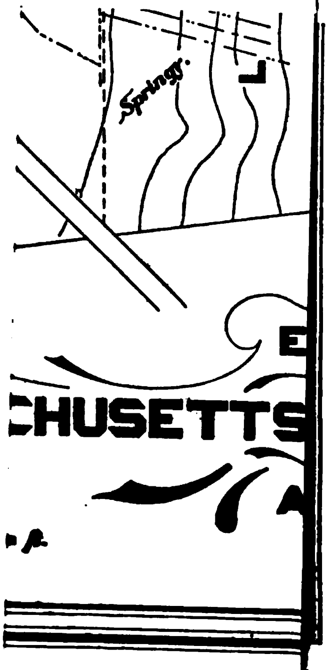

CHUSETTS

Agriculture

VOL. II

MANURES, FERTILIZERS & FARM CROPS, *including* GREEN MANURING AND CROP ROTATION

. . *By* . .

WILLIAM P. BROOKS, Ph.D.

Professor of Agriculture, Massachusetts Agricultural College and Agriculturist, Massachusetts Agricultural Experiment Station.

FIFTH EDITION

Published by

THE HOME CORRESPONDENCE SCHOOL

SPRINGFIELD, MASSACHUSETTS

1-8-43

CONTENTS

VOLUME II

CONTENTS.

CONTENTS.

Preface

This volume is intended for use in connection with Vol. I, which precedes, and Vol. III, which follows it in this series. Vol. I contains complete index. The paragraphs are numbered consecutively with those of the other volumes, and frequent references are given to subjects treated at length in Vol. I. The student is warmly advised always to look up such references unless the matter treated is perfectly fresh in mind and clearly understood. The subjects — Manures and Fertilizers — are most thoroughly and carefully treated in this volume ; — subjects which, as every one admits, are of vital importance. Only when the farmer clearly understands the nature, composition, and adaptations and the proper methods of use of manures and fertilizers can he expect the best economic results. To the student who will master these subjects it may safely be promised that in his first subsequent year on the farm he will reap pecuniary advantages compensating him many times over for all expenditure in money, time, and study. While great importance is attached to a mastery of the scientific principles involved, for such mastery enables one to adapt his practice to conditions which tend ever to vary, the specific advice which is given — advice founded upon the latest results of many most careful experiments — should enable even him who has not such mastery to reap great benefits from a consultation of the pages of this volume.

Green-manuring — a subject which of late years has justly attracted the most widespread attention, for its possibilities are great

— is treated at length. What it can do, what it cannot accomplish, and the limitations to its profitable practice are set forth.

Crop-rotation and its relations to profitable agriculture, to plant-diseases and to insect-damage, are carefully considered; and lastly, each important crop of the farm is taken up; its nature and uses, its soil adaptations, and the manuring it needs are considered; and particulars as to planting, culture, and harvesting are given. The implements found most useful in connection with the various crops are spoken of; and methods of protecting each from insects and diseases are given. The volume is liberally illustrated, most of the illustrations being prepared especially for this book.

Wm. P. Brooks

Massachusetts Agricultural College,
AMHERST, MASS.

AGRICULTURE

VOL. II

MANURES, FERTILIZERS AND FARM CROPS

XLIII — MANURES.

281. Any substance which applied to the soil will increase its productiveness may be called a manure. The productiveness of soils depends upon the presence of certain necessary elements of plant food as well as upon numerous other conditions. If a manure supplies a necessary element of plant food which a plant must take from the soil it is called a direct manure. The only elements ordinarily deficient in most soils are nitrogen, phosphoric acid, and potash (30). Any substance, therefore, which contains either or all of these elements is a *direct* manure. Some materials which do not contain either of these elements of plant food may, nevertheless, increase the productiveness of certain soils. Such substances must be regarded as manures. To distinguish them from manures which furnish nitrogen, phosphoric acid, or potash they are called *indirect* manures. Examples of direct manures are: barnyard and stable manures, wood ashes, nitrate of soda. An example of an indirect manure is lime. Barnyard and stable manures, nitrate of soda, and ashes are used chiefly because they will supply elements which are often deficient in soil. Lime, on the other hand, if needed at all, usually proves useful by its action in rendering inert soil constituents more soluble and more available, by sweetening the soil, or by improving

its texture. It is important to recognize that the *action of some manures may be both direct and indirect, i. e.*, they furnish needed elements of plant food and at the same time tend to produce indirect results which are favorable to productiveness. Barnyard manure, for example, acts both directly and indirectly.

The word manure, in American usage, is often understood to designate only some form of animal excrement, but this use of the word is not correct. The word in its broadest sense includes not only all the animal excrements, and such substances as peat, muck, and leaf mould, but all the various substances bought and sold under the name of fertilizers. The term fertilizer in American usage designates any of the almost innumerable manurial substances other than animal excrements that are largely bought and sold; as, for example, wood ashes, bone meal, nitrate of soda, superphosphate, etc. All fertilizers, strictly speaking, are manures, but all manures in the common use of the word are not fertilizers.

XLIV — FARM MANURES.

282. *The different kinds* — It is proposed to consider under this general subject the different manurial substances which are usually of home or farm origin, though any of them are of course sometimes bought and sold. The kinds which will be considered are: First, the excrements of our larger domestic animals; second, poultry manures; third, night-soil; fourth, muck and peat; fifth, leaf mould; sixth, refuse vegetable substances; seventh, composts; eighth, sea manures.

XLV — THE EXCREMENTS OF OUR LARGER DOMESTIC ANIMALS.

283. Under this heading will be included barnyard, stable, sheep, and pig manures.

284. *Barnyard manure* — This term undoubtedly originally designated a more or less composite mixture containing the excrements of various domestic animals accumulated in a farm or barn yard. At present, however, in American usage the name is used to designate the manure from neat cattle, whether made in stables or barns or in yards.

285. *Stable manure* — As now usually used this term denotes manure from horses, especially that which comes from city or town stables.

286. *Conditions affecting the value of manures* — The conditions which affect the value of manure made from the different classes of animals under consideration are in most essentials the same and all will, therefore, at the outset be considered together.

287. *Dung and urine* — All the kinds of manure under consideration contain, as a rule, both the dung and urine of the animals from which they are made. The dung consists chiefly of the undigested portions of the food, which, however, have first been ground fine by the teeth, and later saturated and softened by the water taken by the animal and by the digestive fluids of the alimentary canal. The undigested portion of the food consists largely of the woody or fibrous tissues of the food eaten, but the dung which contains this undigested portion is in a much better condition to act as a manure than the original material, because it has been ground so fine and softened so much that it will decay very readily. The dung con-

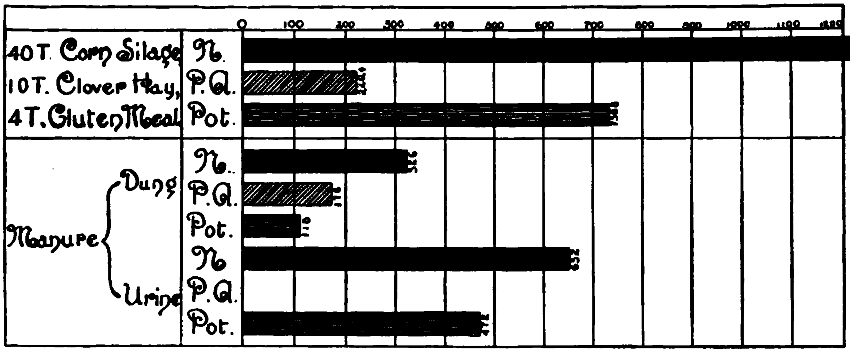


FIG. 56 shows the proportion of the plant food elements voided in the dung and in the urine when the foods specified are consumed by milch cows. The figures indicate pounds.

tains approximately one-third of the total nitrogen, one-fifth of the total potash, and nearly all of the phosphoric acid voided by the animal. Its constituents are not soluble and not in condition to serve immediately as the food of plants. The urine of our domestic animals contains compounds produced as the result of changes which go on in the body in the digested

portion of the food and in the tissues of the body itself. The urine usually contains about two-thirds of the total nitrogen, four-fifths of the total potash, and but very little of the phosphoric acid voided by the animal. The elements found in the urine are in solution, and while not all of them are in such form as to be immediately available, it is a fact that the constituents of the urine become available as food for plants much more quickly than the constituents found in the dung.

288. *Relative amounts of dung and urine* — The relative amounts of dung and urine vary widely with the different animals, and to some extent with the food of the animals. In the case of the ox the total weight of the urine is usually about twice the weight of the dung. In the case of the horse and the sheep there is much less difference and the dung often weighs somewhat more than the urine.

289. *Two classes of conditions affecting the value of manures* — It is a well known fact that the value of barnyard and stable manures, etc., varies widely. This variation is due to two classes of factors, viz.: 1st, factors affecting the excrements as voided; and, 2d, exterior factors.

290. *Factors affecting the value of manures as voided* — The composition of animal excrements is affected in marked degree by the food, by the age of the animal, by products yielded, and by condition.

(*a*) *Food* — Other things being equal, the richer the food the more valuable the manure. The constituents of the manure as voided come, of course, primarily from the food, and it is self-evident that the richer the food given the animal is in the elements of plant food, the richer will be the manure. The manure from animals fed largely on straw or hay will be comparatively poor, that from animals receiving a liberal amount of such foods as wheat bran, gluten meal, and cottonseed meal, will be rich, particularly in nitrogen and in phosphates.

(*b*) *The age* — So long as the animal is making growth, *i. e.*, forming new bone and new muscle, the elements which enter into this new bone and muscle must be taken out of the food, and the excrements, therefore, are poorer than those of animals similarly fed that have completed their growth. The elements chiefly affected are nitrogen and phosphoric acid,

both of which enter largely into the bones, and the nitrogen also into the muscle.

(*c*) *Products* — Such essential elements of plant food as are contained in any of the products for which animals are fed, such as milk or wool, must of course come in the first instance from the food, and, accordingly, there remains so much the less of these elements to be voided in the excrements. Milk contains considerable nitrogen and phosphoric acid, and a moderate amount of potash. Wool contains a large amount of nitrogen, while in the oil or "yolk" is a large amount of potash.

(*d*) *Condition* — If an animal is low in flesh, or in so-called poor condition, it must take from its food the materials necessary to bring the body into a better or well-nourished condition. The excrements from mature animals which are being fattened are richer than those from any other class of farm animals, for fattening animals are storing up in the body almost exclusively fat; and this does not contain either nitrogen, phosphoric acid, or potash in appreciable amounts.

291. *Importance of proper methods of handling and saving* — The conditions affecting the saving and preservation of the elements of value in the excrements affect the value of manures in far greater degree than do those factors which have been considered. The most important of the factors which have an influence are: stable construction and management, the kind and amount of bedding or litter used, the use of chemical absorbents, and the way in which the manure is stored and kept. The object to be aimed at is, of course, the prevention of all loss of valuable constituents. The chief sources of loss are: first, through the escape of urine or natural drainage liquors; second, by exposure to rain and leaching; third, by fermentation. The first two result in a loss of nitrogen and potash, which are chiefly contained in the urine. Fermentation, if not properly controlled, results in a serious loss of nitrogen.

292. *Stable construction and management* — Stable construction and management affect chiefly the losses from the first two of the causes named. In many of the older stables much of the urine was suffered to escape, oftentimes through cracks in the floor on which the animals stood. Fre-

quently, also, the manure when removed from the stable was thrown into a heap in the open air where the rains, and, in some cases, the water from the eaves, as well, soaked through it, carrying away a considerable portion of its valuable constituents. The details of stable construction are, of course, almost infinitely varied. The prevention of loss from the sources named must not be lost sight of. The platform and gutter behind the larger animals must be tight. In some cases the gutter is sloped to an outlet from which urine is led into a tank set to receive it. This plan is in-

FIG. 57. INTERIOR VIEW OF COW STABLE, MASS. AGRICULTURAL COLLEGE.
Manure is carried to pit about 25 yards from stable in carrier which runs on overhead track.

finitely better than it is to allow the urine to escape; but on many accounts it seems preferable to keep dung and urine together. Neither by itself is a well-balanced manure. The dung is poor, both in nitrogen and potash; the urine contains little phosphoric acid. If the two be kept together the manure suits the average crop better than either alone. Moreover, if the urine be separated from the dung, especially in the case of horses, the latter becomes too dry. Manure keeps better, decomposition goes on under better conditions, when it is quite moist. As a rule, then, it seems best to use bedding in sufficient quantity so that the dung and the urine may be

handled together. The usual plan is to clean the stable once or, better, twice daily. Many of the older barns and some of those of modern construction have cellars underneath into which the manure is thrown. If the cellar is water-tight and naturally dry it is a good place in which to put manure ; but the placing of manure in a cellar underneath a stable in which animals are kept is often objectionable on sanitary grounds. Foul odors and gases inevitably find their way from the cellar into the stable in greater or less degree. True, by thorough ventilation of the cellar and by the adoption of precautions which will be considered under "preservation" the disadvantages of the cellar can be in a measure removed. In the modern dairy barn, however, it is believed manure should not be stored underneath the stable in which the cows are kept. A better plan is to provide a covered pit convenient of access from the stable. The manure is then collected in trucks or cars, which are sometimes suspended from overhead tracks and conveyed to the pit. Some prefer to dump the manure from the stable directly into carts and to take it at once to the field. This plan, however, will on most farms be found somewhat inconvenient, as to carry away the manure daily or at such frequent intervals as would be necessary would involve considerable interference with the other work of the farm. As a rule it will be best to provide pits of such capacity that the manure can be stored for a few weeks at least. These pits should be water-tight, as well as provided with a roof. The method commonly

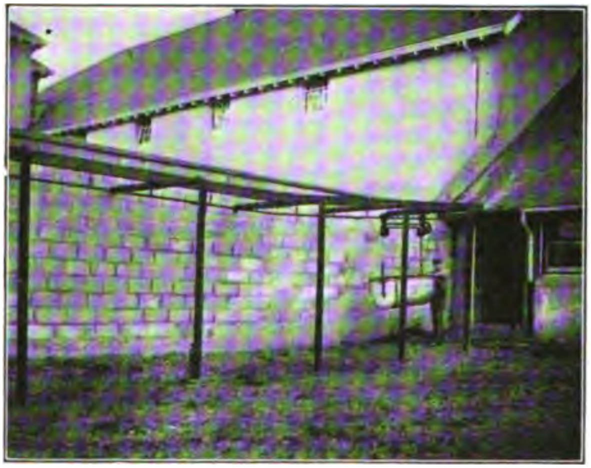


FIG. 57a. CARRIER FOR MANURE COW STABLE, MASSACHUSETTS AGRICULTURAL COLLEGE. The Manure is conveyed to pit or dumped into carts set to receive it.

employed in keeping sheep and young stock is a very satisfactory method of keeping manure. These animals are commonly confined in pens, the manure being allowed to accumulate under them, perhaps for the entire winter. If bedding and absorbents are freely used the animals may be kept clean, the urine is entirely absorbed, and the continual trampling of the animals keeps the manure so compact that no loss through heating and fermentation occurs. Deep stalls are used in some countries for the accomplishment of the same result with the larger animals. The deep stall at the beginning of the season is a water-tight pit of moderate size in which the animal stands. The manger is movable, being raised as the amount of manure beneath the animal increases. Bedding is very freely used and the manure is occasionally leveled. The elements of value in the manure are very perfectly saved under this system, but it appears impracticable under the conditions usually prevailing here.

293. *Bedding or litter* — The character and value of manure is largely affected by the kind and amount of litter used. The objects in view in employing litter or bedding materials are : —

1st. To afford a comfortable bed, and to keep the animals clean.

2d. To absorb and retain urine.

3d. To dilute the manure, making even distribution easier.

4th. To improve the manure in its mechanical condition or by the addition of plant food to it.

5th. To absorb gases to some extent.

294. *Materials commonly employed* — Among the materials available in most parts of the Northeastern states those commonly employed are straw of the various kinds, marsh hay, leaves, corn stover, peat moss, dry muck, fine dry earth, sawdust, and shavings.

(*a*) *Straw* — The straw of the different grains is one of the most satisfactory materials that can be used for bedding. It makes a comfortable and clean bed, is easily used, wears well, has great capacity to absorb urine, and has considerable manurial value. The straw of the different grains differs chiefly in toughness and wearing qualities. The effect of the different kinds upon manure is not very materially different. A ton of straw will usually

contain about 16 pounds of nitrogen, 4 pounds of phosphoric acid, 26 pounds of potash, and 9 pounds of lime. It will be seen that the proportion of potash is quite large. An average ton of barnyard manure contains about 10 pounds each of nitrogen and potash (301). It will be seen, therefore, that a ton of straw contains more nitrogen and potash than a ton of average manure. It follows, then, that by the liberal use of straw the proportions of nitrogen and potash in manure will be increased. Straw of course increases the bulk of manure in proportion to weight. A cord of strawy manure weighs much less than a cord of clear manure and contains less plant food.

(*b*) *Marsh hay*—There are two distinct classes of marsh hay, viz., salt and fresh. Both are used as bedding, the former, naturally, only near the seaboard. Marsh hay, whether salt or fresh, has about the same qualities as straw, though it is somewhat less absorptive, and the salt marsh hay particularly does not decay quite so quickly. There is much variation in the value as litter of marsh hay, as this is affected greatly by the species of plants growing in the marsh. Fresh marsh hay sometimes contains weed seeds which may prove troublesome. The manurial value of the constituents in salt hay is estimated to be about $3.30 per ton; that of fresh marsh hay about $4.75 per ton. The liberal use of either of these kinds of hay would have about the same effect on manure as the similar use of straw.

(*c*) *Leaves*—Leaves are excellent bedding, being best adapted for use with animals confined to pens, such as calves, colts, sheep, and swine. They are rather too loose for use in stables for cows. The supply is limited, and the cost of collection makes their use under most circumstances quite expensive. The manurial value is estimated at about $2.50 per ton.

(*d*) *Corn stover*—Although sometimes used for litter, corn stover in most portions of the Northeastern states is worth more for feed than bedding. If well dried it has fairly good absorptive qualities, but, unless shredded or cut, it is too coarse to be satisfactory. Its manurial value is estimated at about $3.50 per ton.

(*e*) *Peat moss*—The use of peat moss as bedding insures the acme of comfort and sanitary conditions. This material is imported in bales, com-

ing from Germany. Its cost is too great to make its use as a farm bedding practicable. It takes up about ten times its weight of water, while straw takes up only about three times its weight. The use of peat moss in fairly liberal amounts would be favorable to the product of an excellent quality of manure.

(*f*) *Dry muck or peat* — These materials are excellent absorbents if they can be well dried, and they are rich in nitrogen, good samples containing in a given weight fully three times as much nitrogen as is found in average manure. Their liberal use, therefore, would greatly enrich manure in this element. In spite of these facts these materials are not satisfactory bedding for most animals, as when wet they are adhesive, and when dry they are apt to get into the fine hair of the udder of milch cows, and are removed with difficulty. These materials may be used in the gutters behind animals, but should not be placed under them.

(*g*) *Fine, dry sand or earth* — Sand is not a good absorbent, and earth, if very fine, and containing any considerable amount of clay has the same faults as muck. Sand does not contain an appreciable amount of plant food. Its use may contribute to the comfort of animals kept on it, and help to secure good sanitary conditions, especially to free the stable from odors. It does not, however, add to the value of the manure.

(*h*) *Sawdust and shavings* — Sawdust is largely used in many parts of the Northeastern states. Its use is attended with many advantages. When dry, it is a fair absorbent. It is light, clean, coarse enough to brush off from the animals easily, and in many localities can be obtained for the cost of transportation. Sawdust is superior to shavings in its ability to hold its place in the stall, being much less easily moved. It improves the mechanical condition of the manure to some extent, but it is poor in plant food. Shavings are very similar in their characteristics to sawdust. They can be purchased baled at prices which render their use sometimes economical. They give a stable a very light, clean, and attractive appearance, and fresh odor. They have about the same mechanical effect upon manure as sawdust, but do not add materially to its stock of plant food.

XLVI — COMPOSITION OF LITTER.

ONE TON CONTAINS IN POUNDS: —

	Nitrogen.	Phosphoric Acid.	Potash.
Wheat straw	9.6	4.4	16.4
Rye straw	11.2	5.1	18.1
Oat straw	14.4	3.6	23.0
Barley straw	11.4	5.0	23.5
Pea straw	20.8	7.0	19.8
Soy bean straw	14.0	5.0	22.0
Buckwheat straw	13.0	7.1	24.2
Millet straw	14.0	3.6	34.0
Marsh hay	17.2	10.6	54.0
Ferns	....	7.4	37.2
Leaves	15.0	3.2	6.0

295. *Chemical absorbents* — It is later explained (299) that during the fermentation or heating and rotting of manure a portion of its most valuable constituent — nitrogen — is likely to escape into the air in the form of ammonia or carbonate of ammonia, both of which are volatile. The proper use of chemical absorbents may in large measure prevent this loss and at the same time do much to keep the air of the stable pure and wholesome. All must have noticed the strong smell of ammonia in close horse stables in summer. This can be prevented by the free use of chemical absorbents. Among the most useful of these materials are land plaster, kainite, acid phosphate (super-phosphate), and sulfate of magnesia. All these materials help prevent the escape of ammonia into the air, for the reason that the ammonia enters into combination with one of the acids of the substances used and thus forms a salt of ammonia which is not volatile. Land plaster may be very freely used without danger. Sulfate of magnesia or kainite, which among the substances named are most effective, should be used in the stable only in moderate quantities and should be kept in the gutters and not thrown where the animal must stand in them, as they are likely to give cattle sore feet if carelessly or too freely used. The amount of each of these materials required is usually from a pound to a pound and a half per animal daily. The use of kainite serves not alone to prevent loss of ammonia: it also enriches the manure in one of the most

important constituents of plant food,—potash (370, b). It should be remembered that the potash of kainite, when this substance is used in the stable or mixed with manures, is precisely as useful as it would be were the kainite spread directly on the soil. Indeed, it is likely to prove more useful, because mixed with the manure it will be more evenly distributed. The statements just made concerning kainite are almost equally true of the acid phosphate, which, besides helping to prevent loss of ammonia, enriches the manure in phosphoric acid (362, *d*). Each of the materials named may be freely scattered through composts, or in pits or cellars in which manure is stored, with distinct advantage.

296. *Storing and keeping* — The methods by which manures are stored and kept undoubtedly affect their value to a greater degree than any of the conditions which have been considered. It is somewhat difficult so to manage as entirely to prevent loss. Sources of loss are: 1st, escape of the natural drainage found in manure; 2d, leaching due to the soaking of water through the manure (Fig. 58); 3d, losses resulting from the fermentation of the manure. The methods of preventing loss from the first two causes are comparatively easy and have been in large measure indicated under stable management (292). It is not, however, always possible to store manure in water-tight pits or cellars under cover. It must sometimes be piled in the open air. This is undesirable always, but loss can be largely prevented when it must be done if the following rules are observed: —

FIG. 58. Manure stored under eaves. Kept in this manner the soluble constituents are washed away.
After Osgood. Report Board Cattle Commissioners, Massachusetts.

1st. Make the heap upon a level or, better, slightly concave surface so that nothing will flow away from it.

2d. Place the heap upon soil of compact, clayey character, if possible, so that the soluble constituents of the manure may not soak into the soil.

3d. Make the pile compact and of sufficient height so that rain will not soak entirely through it.

4th. Keep the top of the pile flat or slightly concave so that the rain may be absorbed and the pile kept moist.

5th. Use chemical absorbents and cover the heap when it must stand a long time with a few inches of loam, if the season makes this practicable.

The importance of these rules will be more fully discussed under composts (328, 329). It should be remembered that even under the best conditions some loss of manurial constituents is sure to occur from manure which is piled in the open air. In an experiment conducted by the New York Experiment Station it was found that a pile of cow manure, which when fresh weighed 2,398 pounds, in the course of a year lost 2,150 pounds in weight and decreased one-half in bulk. Chemical analysis showed that it had lost 46.6 per cent. of its manurial constituents. Pound for pound manure which has stood in piles in the open air for some time may contain more plant food than fresh manure, but the number of pounds is so much reduced by the exposure that the total plant food remaining is less than the total at the start. The only gain is the improved mechanical condition and increased availability of some of the manurial constituents.

297. *The rotting of manure* — The rotting of all classes of farm manures is a consequence of exposure to the air and the action of microscopic plants (125), whose growth in the manure causes fermentation. Such plants require for growth certain conditions of temperature, air, and moisture, as well as certain food substances — notably soluble nitrogenous bodies, which come chiefly from the urine. These microscopic plants (which are bacteria) may be divided into two classes: 1st, bacteria requiring free oxygen; and, 2d, bacteria which thrive in the absence of free oxygen. Bacteria of these two classes are known respectively as aërobies and anaërobies. A large portion of the essential elements found in fresh excrements is not directly

available as food for plants. It becomes available only on partial decomposition of the manure. The rotting or fermentation of manure may, then, be very useful, but during its progress or under improper conditions very serious loss of nitrogen (which is the most valuable of its constituents) may take place. It is desirable, therefore, to closely study the nature and causes of the changes which go on during the rotting of manure.

298. *Conditions affecting rotting or fermentation of manure* :—

1st. Temperature. In general the higher the temperature the more rapid the fermentation.

2d. Degree of compactness. Fermentation usually goes on more rapidly in proportion as the mass is light and open so that air gains access to all parts of it.

3d. The degree of moisture. Water in manure, as in soils, tends to lower the temperature and thus to check or prevent fermentation. It also in part excludes air. Fermentation, therefore, can be to a considerable extent controlled by the free use of water.

4th. Composition of the manure. The rate at which fermentation will take place in manure depends upon the percentage of soluble nitrogenous matter it contains,— the more soluble nitrogen-containing compounds, the more rapid the fermentation. The soluble nitrogen compounds of manures — as has been pointed out (287) — come chiefly from the urine; hence, it follows that where the urine is all saved and carefully mixed with the manure, fermentation will go on more rapidly.

299. *The effects of decomposition* — As manure rots one of the first changes noticed is the increase in its temperature. If a mass of manure is light, and if it contains a considerable amount of moisture and soluble nitrogen-containing compounds, its temperature rises rapidly. As a result of the heating of the manure a portion of its water is evaporated; the manure becomes more and more dry, and in extreme cases, as in loose piles or heaps, manure may finally become almost perfectly dry. It turns white, and is said to be "fire-fanged." When manure reaches this condition it has usually lost a considerable portion of its valuable constituents — chiefly nitrogen. Another prominent result is the decrease in organic matter which

is, practically speaking, burned. As a result of this destruction of organic matter, a large amount of carbon dioxid passes into the air, and the capacity of the manure to furnish humus to the soil is decreased. At the same time that these changes are going on ammonia and carbonate of ammonia may be formed, and, as both of these compounds are volatile, they may, to a considerable extent, pass into the air. Such are some of the first results of decomposition under unfavorable conditions. Meanwhile, the bacteria connected with fermentation are at work. In those parts of the mass of manure to which the air has access, we find bacteria which feed upon soluble nitrogen-containing compounds, and take oxygen from the air. As a result of the activity of bacteria of this kind, nitric acid is formed. If the manure is exposed to the weather, much of this nitric acid will be dissolved in the rain water and carried into the lower and more compact portions of the pile. In this portion of the pile are found bacteria which feed largely upon the carbon-containing portions of the manure, and take nitric acid for the sake of the oxygen in it. In a certain sense of the word these bacteria *breathe* nitric acid, but in doing so they destroy it. They separate the oxygen from the nitrogen, and the latter escapes into the air in the free form. These bacteria may be called nitrate destroyers.

Summing up the facts which have been stated, we see, then, that under unfavorable conditions rotting manure may lose water and become fire-fanged ; it loses organic matter, so that it carries less humus to the soil ; it may lose ammonia ; and it may lose nitrogen in the free form. The change of the original nitrogen-containing compounds of the fresh excrements into ammonia and nitrates must take place before this nitrogen becomes available as food for plants. These changes will take place in the soil if the manure is applied in the fresh or unrotted condition ; but this is not always possible, and the question therefore becomes important, how can manure be so handled as to promote the favorable changes which have been pointed out, and to prevent losses?

300. *How should manure be kept?* — How manure should be kept in order to favor improvement in mechanical condition and increased availability of its food constituents, and at the same time to prevent loss, must

have been made for the most part clear in the statements concerning the nature and causes of the changes which go on. Summing the whole matter up we may say: It should be kept in a water-tight receptacle to prevent loss from drainage; under cover to prevent leaching; compact and moist to prevent too rapid heating. It should be kept compact, further, in order to prevent too large a formation of nitrates. True, the nitrogen must enter into combination as nitrates before it is available to the plant, but this change goes on more safely in the soil than in a manure heap. There is danger that if it be suffered to go on too largely in a manure heap, a considerable share of it may be destroyed by the nitrate destroyers which live in the lower portions of the heap. Briefly, we may say that the more nearly manure can be kept under conditions similar to those under which fodder is kept in a silo, the more perfectly will its valuable constituents be preserved. In practice the keeping of swine on manure has much to recommend it, as their trampling renders it sufficiently compact for effective preservation. If, at any time, manure is found to be dry, water should be added. It will be remembered in this connection that if any of the chemical absorbents have been used in the stable, scattered over the manure as it accumulates, the danger of loss of ammonia is greatly decreased.

301. *The composition and value of farmyard manure* — Farmyard manure is a very complex substance. It contains more or less of all the elements which were contained in the food given to the animals and in the bedding. It is rich in organic matter, being composed chiefly of vegetable substances. This organic matter is a source of humus to the soil and may be of much value. Those elements of plant food which are not ordinarily deficient in the soils, such as lime, magnesia, sulfur, etc., which are found in manures, are not without their value; and yet, it is customary to value manures on the basis of the nitrogen, phosphoric acid, and potash they contain, and most analyses of manure are so carried out as to determine the proportion of those constituents and the total dry matter only. It is indeed true that the proportion of nitrogen, phosphoric acid, and potash present in manures affects their value to a greater extent than the proportion of any other constituent; but it is not by any means fair to make a

direct comparison between farm manures and fertilizers on the basis of the relative amounts of nitrogen, phosphoric acid, and potash. Soils need humus. Manure supplies this — fertilizers do not. And further, though soils contain such amounts of lime, magnesia, and other elements of subordinate importance that their addition is not ordinarily followed by increase of crop, yet it may be feared that but for the fact that most farmers use manures which contain these subordinate elements soils would gradually lose productiveness, as the supply of these elements, should they be steadily drawn upon by the crops and never replaced, must ultimately become reduced below the limit necessary for the production of good crops. Comparison, then, between farm manures and fertilizers on the basis of nitrogen, phosphoric acid, and potash is unjust to the manure. Different manures, however, may be justly compared with each other on this basis. The average of many analyses of farmyard manure made in the Experiment Station at Amherst, Mass., shows such manures to contain: Water, 67.6 per cent.; nitrogen, 0.465 per cent.; phosphoric acid, 0.326 per cent.; potash, 0.485 per cent. In this average are included samples from twenty-six farms from many different parts of the state. The average for twelve well-made samples of manure, mostly from milch cows, on which hogs were kept as it accumulated was as follows: Water, 65.9 per cent.; nitrogen, 0.454 per cent.; phosphoric acid, 0.333 per cent.; potash, 0.561 per cent. The most striking difference between the two averages is in the potash, of which the Amherst sample contains considerably the more. It is believed that this must have been due to the fact that under the system there followed all the urine was saved, while in the case of the manure from many of the private farms the percentage of potash was so low that it was evident there must have been loss of the urine, or leaching, or perhaps both. Snyder gives the following as the average and the range in farmyard manures for the three elements under consideration: —

Nitrogen, 0.50 per cent. Range from 0.4 to 0.8 per cent.
Phosphoric acid, 0.35 per cent. Range from 0.3 to 0.9 per cent.
Potash, 0.50 per cent. Range from 0.3 to 0.9 per cent.

It is believed that for practical purposes one will be sufficiently accurate

in estimating well-kept manure to contain ½ of 1 per cent. each of nitrogen and potash and ⅓ of 1 per cent. of phosphoric acid. On this basis a ton of manure would contain 10 pounds each of nitrogen and potash and 6⅔ pounds of phosphoric acid. It has been found at Amherst that a cord of farmyard manure, chiefly from milch cows, which has been well preserved without loss of urine but without exposure to the weather, weighs a little more than 3 tons. A cord of such manure, therefore, should contain about 30 pounds each of nitrogen and potash and 20 pounds of phosphoric acid. Nitrogen can be bought at the present time (1901) in fertilizers at about 14 cents a pound, phosphoric acid in available form at about 5 cents a pound, and potash at about 4.5 cents a pound. On this basis the money value of the nitrogen, phosphoric acid, and potash in a cord of manure amounts to about $6.55. True, these elements of farmyard manures are not equally as available as in most fertilizers, but offsetting this lack of availability we have the value of the humus and the possible value of the other elements of the manure, such as lime, magnesia, sulfur, etc. This figure, if it can be used at all, must be understood to estimate the value of the manure on the field where it is to be used. Manure is very bulky in proportion to the plant food it contains and cannot therefore be transported to any great distance and used at a profit. By the selection of very concentrated fertilizers we can obtain in about 360 pounds of fertilizers as much nitrogen, phosphoric acid, and potash as is contained in a cord or 3 tons of manure. To transport the plant food in fertilizers, therefore, costs but a very small fraction of the amount required in the case of manures. The ordinary farmer, depending upon the more common field crops for his income, should conserve and use all the manure made on the farm to the utmost extent. It can seldom be advisable for such a farmer to purchase manure at the prices at which it can ordinarily be bought. It is not believed that with fertilizers at their present prices a farmer can afford to give more than $1.00 per ton for good average manure, and not even so much as that if the haul is long.

302. *The amount of manure made on the farm* — The experienced farmer knows from results in previous years about what quantity of manure will be made on the farm from a given number of animals. For the beginner some

rule whereby the amount which will be made can be estimated with reasonable accuracy will be useful, because only when the amount of manure which will be available for use is known, can plans for the ensuing year be intelligently made. As the result of careful experiments German investigators give the following rules : To determine the amount of manure which will be made, multiply the dry matter in the food consumed by the different classes of animals by the figures given below : —

For the horse by	2.1
For the cow by	3.8
For the sheep by	1.8

To the product in either case add the weight of the bedding used. The horse of average size consumes daily about 24 pounds of dry matter in its food, and makes, therefore, 2.1 times 24 pounds, or 50 pounds of manure a day. The cow consumes daily about 25 pounds of dry matter, and makes 3.8 times 25 pounds, or 95 pounds of manure daily. A 125-pound sheep consumes about 3 pounds of dry matter daily, and makes 1.8 times 3 pounds, or 5.4 pounds of manure daily. If horses are used for work and are out of the stable a part of the time a suitable reduction in the amount of manure must be made. If cows are in pasture a portion of the time a reduction is of course required. From these figures as a basis, knowing the number of animals he keeps, the beginner will have no difficulty in estimating the quantity of manure he will make in pounds. The applicability of these figures to the conditions prevailing on American farms has not been thoroughly tested ; and it is here pointed out that in such experiments as have been made in this country to determine the amount of manure which is made from a given number of animals, the results have usually been lower than they would be on the basis of these German rules. In one experiment carried out at Cornell for the five winter months with the equivalent of 47 full grown cows, the total amount of manure made was 199 tons, or 4¼ tons per animal. It is not clear from the published account that there was no loss of manure in the experiment.

303. *Estimation of the plant food in manure* — The amount of plant food which is contained in the excrements from animals fed on the farm can

be estimated with considerable accuracy. The knowledge of what the manure contains should prove of value to the intelligent farmer, for having that knowledge he will be able to apply manures for the several crops more intelligently and more wisely. He will also be able to more wisely select fertilizers for use in connection with his homemade manures. To estimate the plant food which will be contained in the manure, it is essential to keep an account of the kinds and amounts of feed consumed by the animals of the farm. The composition of all ordinary feeds is known, and is published in most experiment station reports. From the tables given in such reports the farmer can quickly determine the number of pounds of nitrogen, phosphoric acid, and potash in any given quantity of the feeds used. Many experiments have been carried out with a view to determining what proportion of these elements taken into the bodies of the animals in their food will be voided in their excrements. From what has been said (290, *a*), it will be remembered that the proportion of the plant food elements contained in the feeds consumed which is voided by different classes of animals varies. For practical use, however, it is believed that the following statements are sufficiently accurate. In the case of milch cows it is safe to estimate that 80 per cent. of the manurial constituents found in the food will be voided in the excrements. In the case of fattening cattle or hogs 90 per cent. will be so voided. Whether or not the quantity of nitrogen, phosphoric acid, and potash thus estimated, will be found in the manure as it is taken to the field depends of course upon whether the manure has been carefully saved and handled. If suitable precautions have been taken, the amounts of these elements obtained by this calculation will be found in the manure; but in proportion as the method of handling has been careless, the manure may contain less of these elements, especially of the nitrogen and of the potash. To facilitate calculation as to the contents of homemade manure, a table is given showing the number of pounds of the different most essential elements of plant food in 100 pounds of some of the more commonly used feeds:—

FERTILIZING INGREDIENTS OF FODDER ARTICLES.

	Pounds in 100.			
	Water.	Nitrogen.	Phosphoric Acid.	Potash.
Green Fodders:				
Corn fodder	79	.41	.15	.33
Japanese barnyard millet	75	.46	.11	.49
Oats	83	.49	.13	.38
Soy beans	70	.84	.20	.71
Corn silage	80	.42	.13	.39
Hay and Dry Coarse Fodders:				
Corn stover	20	.92	.26	1.22
English hay	15	1.27	.29	1.50
Rowen	15	1.70	.46	1.56
Timothy	15	1.19	.33	1.40
Salt hay	15	1.06	.23	.65
Millet	15	1.22	.46	1.61
Red clover	15	2.01	.41	2.11
Roots and Tubers:				
Sugar beets	87	.22	.10	.48
Mangolds	88	.15	.14	.34
English turnips	90	.17	.12	.38
Rutabagas	89	.19	.12	.49
Potatoes	80	.29	.08	.51
Grains:				
Corn	10.9	1.82	.70	.40
Oats	9.0	2.10	.68	.48
Soy beans	18.3	5.30	1.87	1.99
Flour and Meal:				
Corn meal	14.1	1.92	.71	.34
Corn and cob meal	9.0	1.41	.57	.47
By-Products:				
Cottonseed meal	8.2	6.70	2.47	1.83
Cleveland linseed meal	8.0	5.83	1.70	1.25
Gluten meal	9.6	6.04	1.43	1.06
Gluten feed	8.2	3.72	.34	.06
Wheat bran	9.9	2.36	2.10	1.40
Wheat middlings	10.2	2.75	1.25	.75

It is, of course, evident that we should find in a manure, in addition to the nitrogen, phosphoric acid, and potash contained in the excrements of the animals, whatever is contained in the bedding and in the stable absorbents used. To make perfectly clear the method to be followed in estimat-

ing what the manure made on the farm contains let us take an example. Suppose a farmer keeps ten cows and two horses. The period of winter feeding may be said to last about 200 days. The daily food of the cows, each : —

Corn silage,	40 pounds.
Clover hay,	10 pounds.
Cottonseed meal,	2 pounds.
Wheat bran,	4 pounds.

To obtain the total amount of food given to the cows we have, of course, to multiply by the number of cows and the number of days.

Let us suppose that the horses receive daily : —

Timothy,	15 pounds.
Oats,	5 pounds.
Corn,	5 pounds.

The total amounts of feeds used, then, will be as follows : —

Corn silage,	80,000 pounds.
Clover hay,	20,000 pounds.
Cottonseed meal,	4,000 pounds.
Wheat bran,	8,000 pounds.
Timothy hay;	6,000 pounds.
Oats,	2,000 pounds.
Corn,	2,000 pounds.

To obtain the amount of nitrogen, phosphoric acid, and potash in these feeds we have only to multiply the figures shown in the table by the number of hundreds of pounds. Thus, for example, we have 80,000 pounds of corn silage which is 800 hundred. We therefore multiply by 800 the number of pounds of each of the plant foods shown by the table. Making similar calculations for each of the foods used we get the results shown in the following table : —

PLANT FOOD IN FEEDS USED.

FOR TEN COWS.	Nitrogen. Pounds.	Phosphoric Acid. Pounds.	Potash. Pounds.
Corn silage, 80,000 pounds	336	104	312
Clover hay, 20,000 pounds	402	82	422
Cottonseed meal, 4,000 pounds	268	98.8	73.2
Wheat bran, 8,000 pounds	188.8	168	112
Total	1,194.8	452.8	919.2
FOR TWO HORSES.			
Timothy hay, 6,000 pounds	71.4	19.8	84.0
Oats, 2,000 pounds	42.0	13.6	9.6
Corn, 2,000 pounds	36.4	14.0	8.0
Total	149.8	47.4	101.6

In the case of mature animals practically all the nitrogen, phosphoric acid, and potash in the food will be voided in the excrements. In the case of the cows we expect to find in the excrements 80 per cent. of the amounts shown by the above table. Calculation gives the following results: Nitrogen, 955.84 lbs.; phosphoric acid, 362.24 lbs.; potash, 735.36 lbs. To these figures we have to add the amounts contained in the food given to the horses, all of which we expect to find in the excrements. Carrying out this calculation we have: 1105.64 lbs. nitrogen; 409.64 lbs. phosphoric acid; and 836.96 lbs. potash.

Let us suppose that in bedding these animals we have used 12,000 pounds of oat straw. From the table in paragraph 14 we find that this will contain 86.4 lbs. nitrogen, 21.6 lbs. phosphoric acid, and 138 lbs. potash. Adding this we have of nitrogen 1192.04 lbs.; of phosphoric acid 431.24 lbs.; of potash 974.96 lbs., all of which should be found in the manure unless there has been loss. It should perhaps here be pointed out that horses, as a rule, are out of the stable a considerable share of the time during the hours of daylight. When this is the case a reduction must be made for the loss which is a consequence. Thus, for example, if the two horses we have supposed to be kept are worked an average five days a week for ten hours a day they are absent from the stable 50 hours each week, or in 200 days,

which is about 30 weeks, they will be out of the stable 1,500 hours, which is almost one-third of the total time.

The intelligent farmer will wish to know not simply the total amount of nitrogen, phosphoric acid, and potash contained in the manure made,—he will wish to know how many pounds of these elements will be contained in an average load such as would be hauled to the field for application. He will wish to know this in order that he may calculate how much plant food he is applying to the soil when he gives a dressing of a certain number of loads of manure. To obtain this information we must make use of the rules given in paragraph 302. It is there stated that to find the amount of manure made from cows we must multiply the dry matter in their food by 3.8 and add the bedding. For horses we must multiply the dry matter in the food by 2.1 and add the bedding. The table contained in this paragraph enables us to calculate the amount of dry matter in the food given to the cows and in that given to the horses, for all that portion of the food which is not water is dry matter. Thus, for example, the percentage of water in corn silage is given as 80; corn silage therefore contains 20 per cent. dry matter. In the 80,000 pounds fed to the cows we shall, therefore, have 16,000 pounds of dry matter. Similar calculations for the other feeds given the cows give the following results:—

Corn silage, 80,000 lbs.,	16,000 lbs. dry matter.
Clover hay, 20,000 "	17,000 " " "
Cottonseed meal, 4,000 lbs.,	3,672 " " "
Wheat bran, 8,000 lbs.,	7,208 " " "

The total dry matter in the food of the cows, therefore, is equal to the sum of these, or 43,880 lbs. Multiplying this by 3.8 we have 166,744 pounds.

For the food of the horses the calculation is as follows:—

Timothy hay,	6,000 lbs.,	5,100 lbs. dry matter.
Oats,	2,000 "	1,820 " " "
Corn,	2,000 "	1,782 " " "
Total dry matter,		8,702 "

Multiplying this by 2.1 we have 18,274.2 lbs. For bedding we have used 12,000 pounds of straw. Adding this to the total weight of the excrements

of the cows and horses we have 197,018.2 pounds or 98.5 tons. The farmer may estimate safely then that he has made 98.5 tons of manure containing 1,192.04 lbs. of nitrogen, 439.24 lbs. of phosphoric acid, and 974.96 lbs. of potash. One ton or one load therefore would contain: nitrogen, 12 lbs.; phosphoric acid, 4.4 lbs.; potash, 10 lbs. This is very close to the amounts estimated on the basis of the average composition of farmyard manures, viz.: nitrogen, 10 pounds; phosphoric acid, 6.7 pounds, and potash, 10 pounds (301).

304. *Dung, urine, and drainage liquors compared*—To bring out more fully than has thus far been done the serious nature of the loss when any portion of the urine or the natural drainage from moist manure is allowed to escape, figures showing their composition are presented for the purpose of comparison. The figures in the first two tables are taken from Wolff, a German authority.

COMPOSITION OF FRESH EXCREMENTS.

1,000 pounds fresh dung contain:—

	Water. Pounds.	Nitrogen. Pounds.	Phosphoric Acid. Pounds.	Alkalies. Pounds.
Horse	760	5.0	3.5	3.0
Cow	840	3.0	2.5	1.0
Swine	800	6.0	4.5	5.0
Sheep	580	7.5	6.0	3.0

1,000 pounds fresh urine contain:—

	Water. Pounds.	Nitrogen. Pounds.	Phosphoric Acid. Pounds.	Alkalies. Pounds.
Horse	890	12.0	....	15.0
Cow	920	8.0	....	14.0
Swine	975	3.0	1.25	2.0
Sheep	865	14.0	0.5	20.0

The potash of both the dung and urine is included with lime, magnesia, etc., to make up the so-called "alkalies." Attention is called to the fact that notwithstanding the urine contains relatively much more water than

dung the quantities of nitrogen and of alkalies in equal quantity by weight are much greater in the former than in the latter. The loss, then, of a pound of urine is a more serious matter than would be the loss of a pound of dung.

COMPOSITION OF DRAINAGE LIQUORS.

1,000 pounds contain :—

	Water. Pounds.	Nitrogen. Pounds.	Phosphoric Acid. Pounds.	Potash. Pounds.
Drainage from gutter behind milch cows	932	9.8	2.4	8.8
Drainage from manure heap..........	820	15.0	1.0	49.0

It will be seen that these drainage liquors are much richer both in nitrogen and in potash than the average of farm manures, 1,000 pounds of which (301) have been stated to contain nitrogen 5 pounds, phosphoric acid 3.3 pounds, and potash 5 pounds. In the knowledge of these facts no farmer should rest satisfied until he has taken such steps as will prevent loss of the fluid portion of manures.

305. *Manure from different farm animals* — One of the most important points of difference between the manures from the different larger domestic animals is in the relative amounts of organic matter, or, in other words, in the degree of moisture or dryness of the different manures. The following table shows the variation in this respect :—

Per Cent.	Horse.	Cow.	Sheep.	Pig.
Water..............................	77.25	82.45	56.47	77.13
Organic matter.....................	22.75	17.55	43.53	22.87

In general the richness of manure in the different elements of plant food increases with the amount of organic matter, and decreases with the amount of water.

(*a*) *Horse manure* — Horse manure is generally more valuable than the manure of other farm animals provided it has been well kept. It is richer in nitrogen than the manure of either the cow or the hog, and is much more

liable to fermentation. On this account it is called a hot manure, and, unless kept very compact and moist, it is liable to fire-fang. This quality of quick fermentation and heating makes it the most valuable manure for hot beds as well as for cold, wet soils. As usually obtained from city stables its composition and value vary greatly on account of variation in the amount of litter, and the way in which the manure has been saved and handled. This manure averages much lighter in weight than cow manure, usually ranging between about 1½ to 2 tons per cord.

(*b*) *Cow manure* — This contains, as shown by the table, considerably more water than the manure of either horses or sheep. It is consequently usually poorer in plant food. Largely because it is so watery as well as relatively poor in soluble nitrogen compounds, cow manure ferments and heats slowly. It ranks as a cold manure.

(*c*) *Hog manure* — Hog manure also is relatively watery as shown by the table. It is relatively poor in nitrogen and rich in phosphoric acid, decomposes slowly, and must be ranked as a cold manure.

(*d*) *Sheep manure* — Sheep manure is generally quite dry, and is commonly the richest of the farm manures, that from poultry excepted. Owing to the fact that it is generally allowed to accumulate in pens, and to the further fact that the amount of urine voided by sheep is relatively small, the elements of value in sheep manure ordinarily suffer less loss than is common from other kinds of farm manure. When, however, sheep manure is thrown up into loose piles, which must generally be done in order to bring it into suitable mechanical condition to spread, it very rapidly undergoes decomposition and heats quickly. It is then very likely to lose a portion of its nitrogen in the shape of ammonia. To prevent this it is well to scatter kainite or land plaster in layers as the pile of manure is built up.

306. *Mixture of manure from different animals* — The mixture of the manures from the different animals of the farm is often a great advantage. A mixture of horse and cow manures is particularly useful, as the former ferments too rapidly and the latter too slowly. The first is apt to become too dry and the latter is sometimes too moist for convenient handling. By mixture we therefore secure a more favorable condition, both for

fermentation and handling. Spreading horse manure daily in the gutters behind the cows secures perfect mixture but is open to the objection that the air of the cow stable is somewhat vitiated as a result of the presence of the horse manure. It is preferable to throw both kinds of manure together into a pit or cellar in which the surface should be kept level. In such pit or cellar it will be a great advantage in most cases, as far as the preservation of the manure is concerned, to keep hogs. These should be furnished a dry and clean bed and a clean place for feeding. It will not harm them to trample over and work in the manure if the place is well ventilated, while the manure will be greatly improved.

XLVII — THE APPLICATION OF FARMYARD MANURES.

307. *Should manures be applied fresh or rotted?* — The answer to this question must be that it depends upon conditions. It is true as a rule that the fresher we can get manure to the field the less is the loss of plant food. As has been stated, it is difficult so to keep manures and so to control fermentation that there shall be no loss. Recognizing this fact many advocate taking manures to the field about as fast as they are made. Besides the point which has been named, it may be further urged in favor of this practice: first, that fresh manure carries more humus to the soil than that which has been rotted, as in the process of rotting a portion of the organic matter is destroyed; second, most of the manure made upon the farm is produced during the winter months. On the majority of farms the amount of work at that season is comparatively little. In the spring, on the other hand, work is much more pressing. It is a great practical advantage, therefore, and may be a considerable source of economy in the cost of getting out the manure to do the work about as fast as the manure is made during the winter. The question will doubtless be asked, however, if manure is spread during winter does it not suffer serious loss through lying upon the surface? In considering this question it is important to remember that the proportion of soluble constituents in fresh manure is less than in rotted. It is further important to remember that fresh manure does not contain any considerable amount of ammonia, while rotted manure

may. If manure is spread during the winter months, before the nitrogen of the urine or dung is converted into ammonia by the process of decomposition, there is nothing of value in the manure which can escape into the air ; and ammonia will not form to any considerable extent at the low temperatures prevailing in winter in the manure which lies upon the surface. The only source of loss, then, would appear to be through the washing out and escape over the surface of a portion of the soluble constituents of the fresh manure. This loss may in some situations be serious. If, however, the field is fairly flat, or if on a moderate slope it has been cross plowed with a rough furrow late in the fall, the amount of wash over the surface will not be great. If the winter is open and the rains and thaws are frequent the manure as it lies upon the surface will, of course, be leached, but if the water which flows through the manure soaks into the soil this does not involve any loss. It doubtless would be a mistake to apply manure on grass land or on steep slopes in late fall or winter when it must be allowed to remain upon the surface, but it should be remembered that this loss is likely to be less with fresh manure than with rotted. It is doubtless to be expected that when any fresh manure is spread during the fall or winter there must be some loss of manurial value, but in many cases it appears to be true that the saving in the cost of application is sufficient to more than offset such loss as is likely to occur. Whether manure should be applied fresh or first rotted must be determined in part by the nature of the soil and by the crop. For cold, heavy soils coarse, quick fermenting manures are to be preferred. They increase the porosity of such soils and their decay in the soil improves its mechanical condition. For the lighter soils the finely rotted or cold manures should be preferred. Market garden crops must usually be manured with fine, well rotted, quick acting manures, while for crops like grass and corn the slower acting manures may be selected. There appears to be much need of further light on the general question of the expediency of spreading fresh manure on fields in winter. Many good farmers follow this practice but there are also many who believe it to be a mistake. The comparative results of the two systems will undoubtedly vary to a considerable extent in accordance with the variations

in season. It is believed that during many winters the loss of manurial value would be exceedingly small, but we doubtless have occasional winters, such, for example, as that which prevailed in Massachusetts in 1899 and 1900, when, owing to the frequent heavy rains and thaws, the loss in the wash over the surface was large. Only a careful series of experiments extending over a number of years can be expected to solve this question.

308. *The amount of manure to be used* — There is, of course, a very wide variation in the amount of manure applied for different farm purposes. New England farmers would generally regard from 5 to 8 cords of farmyard manure, chiefly from cows, as an adequate dressing for field purposes; while market gardeners sometimes use manure at the enormous rate of 30 or 40 cords per acre. It is believed that in the farm practice of the Northeastern states it will generally be found best to use manure with such moderation as may be necessary to make it cover practically all the tilled land yearly. If the amount made is insufficient, as it will be in many cases, to allow a sufficiently large dressing to produce good crops, fertilizers should be used in connection with the manure. It is undoubtedly better, unless some special reason exists why manure should not be used, to employ manure in moderate quantities in connection with fertilizers on all the tilled land than to use heavy dressings of manure alone over some fields and fertilizers alone on others. Most of our fields need additional humus. This, as has been stated, the manure supplies. It is recognized, of course, that conditions may sometimes render it inexpedient to use manures on certain fields or on certain crops. In the case of fields which lie at a distance from the homestead it may be preferable to depend wholly upon fertilizers rather than to incur the large expense of hauling manures; while for certain crops manure may injure the quality, as in the case of tobacco; or it may render the crop somewhat more subject to certain diseases, as, for instance, scab in potatoes; or the weed seeds or its coarse mechanical condition may be objectionable, as in the case of some of the small crops such as onions. In deciding upon the amount it is well to keep in mind the fact that with even distribution of manure in fine mechanical condition a relatively small amount may be equally effective with a larger application more

carelessly made. It may, further, be pointed out that in the case of the heavy soils it may be perfectly safe to make large applications at wide intervals, since the nitrogen of farmyard manure is not very liable to loss in such soils. For the lighter soils smaller applications at more frequent intervals are generally to be preferred.

309. *Manner of application* — The object which should be aimed at in the application of farmyard manure is even distribution of finely divided manure. The manure may be first left in small heaps from which it is later spread, or it may be spread directly from wagon, cart, or sled. A machine which does the work has been brought to a fair degree of perfection. Whether it will be better in the case of hand work to spread directly from the cart, or to first dump the manure in small piles, will depend largely upon the relative cost of team and hand labor. Team work is economized by dumping the manure in small piles as rapidly as possible, but manure which is first dumped in small piles is seldom spread as evenly as that which is spread directly from the wagon. Where several teams are at work it will generally be found better practice to keep the teams moving, to have extra help in loading and a man in the field to spread. Where one man is working alone it is believed that it is nearly always better to spread from the wagon. If manure is put into small heaps it should be remembered that it never should be allowed to remain in such heaps long. Should a rain come before they are spread the soluble constituents of the manure are washed through such heaps in excessive quantities and the spot where the heap has stood is made over-rich. It is sometimes advisable to haul manure to the field where it is to be used during the winter season and to pile in large heaps. This is especially good policy where the haul is a long one. The directions which have been given for piling manure out of doors should in such cases be observed as far as circumstances render possible (296).

Manure spreaders are in favor with some, but a careful trial and observation have convinced the writer that they are not of practical value to the ordinary farmer unless under rather exceptional conditions. The chief advantages connected with the use of these machines are even distribution, and the fine mechanical condition in which they leave the manure on the

surface. Where the haul is short they will be found more useful than where it is long. They have been found very convenient for top dressing grass lands near barns. The chief objections to the use of these machines are: —

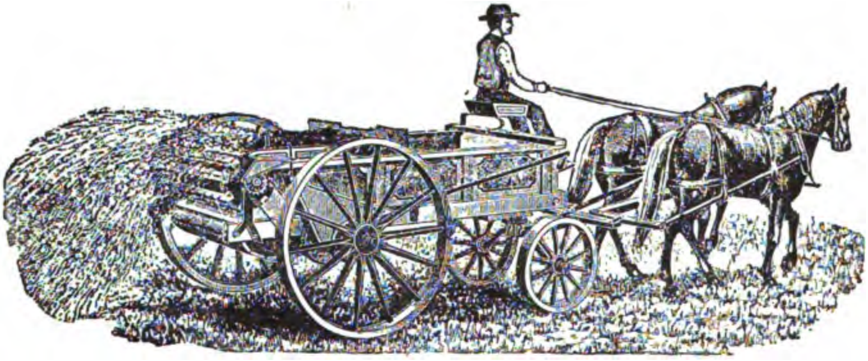


FIG. 59. MANURE SPREADER.

1st. The quantity of manure they will put on at one application is too small in many cases to suit conditions.

2d. The draft on plowed land or that which is wet is very heavy.

3d. They often need repairs which are expensive.

4th. The weight of the spreader is so great that the proportion of dead load is too large to make a manure spreader practicable where the manure must be hauled any considerable distance. Wherever operations are conducted upon a large scale and especially if manure is to be applied to fields which are near the place of production or storage, the manure spreader is an indispensable farm machine.

As a general rule, it is believed that farmyard manures should be put near the surface in the case of tillage. The wheel harrow will work it into the soil and cover it sufficiently in most cases. If, however, manure be exceptionally coarse, or if the land is to be occupied by a crop requiring unusually careful preparation of the soil, it may be better to plow in.

XLVIII — POULTRY MANURE.

310. *Comparative quality* — Poultry manures, if well saved, are richer than the other farm manures. The principal reasons are two: 1st, the

food of poultry is richer as a rule, and, 2d, the excretion corresponding to the urine of the larger domestic animals is semi-solid and voided with the dung. It is not therefore subject to waste by running off. Poultry manures, as a rule, are very rich in nitrogen and phosphoric acid because the foods given to fowls are rich in these elements (grains and animal foods). These manures are *relatively* poor in potash, although they may contain a larger percentage of this element than do the manures of the larger animals.

311. *Composition* — The composition of poultry manures, like that of others, is subject to considerable variation, the conditions producing these variations being for the most part similar to those acting in the case of other manures. The table shows the results of analyses : —

COMPOSITION OF POULTRY MANURES.

	Water. Per Cent.	Nitrogen. Per Cent.	Phosphoric Acid. Per Cent.	Potash. Per Cent.
Hen manure, fresh, according to Storer	56.00	1.60	1.50-2.00	0.80-0.90
Hen manure, fresh, analysis Massachusetts Agricultural Exp. Station	69.76	1.91	1.00	0.33
Hen manure, dry, average two analyses, Goessmann	8.35	2.13	2.02	0.994
Duck manure, fresh, according to Storer	56.60	1.00	1.40	0.620
Goose manure, fresh, according to Storer	77.10	0.55	0.54	0.95
Pigeon manure, according to Storer....	52.0	1.75	1.75-2.00	1.00-1.25

312. *Amount of manure made by poultry* — Storer is the authority for the statement that careful experiment in Belgium indicates that a hen of average size would make about 12 pounds of manure yearly; a turkey or goose about 25 pounds; a duck about 18 pounds. The amount of manure made by poultry doubtless varies with the feed,— the coarser the feed the greater the amount. However, in the light of results obtained at the Hatch Experiment Station, Massachusetts, it appears impossible to believe that these Belgian figures can be correct. In one experiment including about 120 fowls, extending from March 1 to July 8, a period when the nights were relatively short, the manure collected from the dropping boards amounted to a little over .1 of a pound per fowl per night. In another experiment including 20 fowls, and extending from April 7 to August 9, thus

covering the period of the shortest nights in the year, the average droppings per hen per night amounted to a little less than .07 of a pound. The nights during the period covered by these experiments could not have averaged more than about 9 hours in length, being, therefore, only about ¾ of the average length of the nights for the year. Increasing the above amounts for these figures it would appear that the droppings per hen per night may be expected to vary between about 1-11 and ⅛ of a pound, or, for a year of 365 days, from about 33 to 45 pounds. This is probably only about one-half of the total droppings, although, unless the fowls are kept in very close confinement, it must include nearly all that would be saved for application to the fields of the farm.

313. *Characteristics and availability of poultry manure* — Poultry manure ferments very quickly, no doubt chiefly because of its highly nitrogenous character. As it is often handled it loses very much of its nitrogen in the form of compounds of ammonia, which are very rapidly formed and which will escape unless means to prevent are taken. The plant food constituents of poultry manure become available in a shorter time than those of the coarser farm manures. The poultry manures, if they have been well kept, contain plant food in much less bulk than the ordinary farmyard manures. They must be looked upon, not as a source of humus, but simply as carriers of plant food.

314. *Means of preventing loss of nitrogen* — The well constructed poultry house has a so-called dropping board beneath the roosts. On these the excrements dropped during the night fall, and from it they should be frequently removed ; no doubt best daily, although during the cooler weather removal two or three times a week will answer fairly well. It will be found best to sprinkle the dropping boards whenever they are cleaned with fine, dry earth of some kind. Perfectly dry muck would be excellent. The manure as it is removed from the dropping boards should be stored where it will be kept dry. It may be put either in heaps or in boxes or barrels, as may be convenient. Whenever fresh material is added it should be liberally sprinkled either with plaster or finely powdered kainite, as these materials will do much to prevent ammonia from escaping

into the air as it forms. The plaster is superior to the kainite in its effects upon the mechanical conditions of the manure, which will become moderately dry so that it can be finely divided and applied conveniently. It is not, however, quite so effective as a means of holding ammonia as the kainite. The only objection to the use of the latter is that it tends to keep the manure very moist. If fine, dry earth can be used liberally, however, this difficulty can be overcome. Under these circumstances the use of kainite is to be very strongly recommended. It should be remembered that this contains considerable potash (about 13 per cent.) and since, as has been stated, poultry manures are relatively poor in potash, the mixture of kainite with them produces a better balanced manure. In one experiment in the Hatch Experiment Station, Amherst, Mass., extending from April 7 to August 9, the droppings from one house were placed alternately in two pails which were kept closed and under cover. Whenever droppings were added to one pail they were sprinkled with kainite. The other pail was left without the addition of anything. The total amount of kainite used was 15.5 pounds. The manure remained in the pails until October 25. It was then spread under cover to dry, at which time it was estimated that the manure to which kainité had been added had one-third greater bulk than the other lot. It appeared to be nearly in its natural condition, moist, with the individual castings distinct and with a very slight odor of ammonia. The lot of manure to which no kainite had been added was partly decomposed and was a homogeneous mass. The top was dry and lumpy, the bottom moist and salvy. There was no odor of ammonia. The manures were allowed to dry, being occasionally stirred, from October 25 to December 4. The lot to which the kainite had been added weighed 66.25 pounds. It was fairly moist but would crumble. It had the characteristic odor of fresh hen manure and a slight odor of ammonia. The lot without kainite weighed 21.25 pounds, being very dry. It possessed no odor other than any dried manurial substance. These manures were carefully sampled and analyzed with the following results: —

MANURE TO WHICH NO KAINITE WAS ADDED.

Water. Per Cent.	Nitrogen. Per Cent.	Phosphoric Acid. Per Cent.	Potash. Per Cent.
9.66	1.83	3.93	1.48

MANURE TO WHICH KAINITE WAS ADDED.

Water. Per Cent.	Nitrogen. Per Cent.	Phosphoric Acid. Per Cent.	Potash. Per Cent.
41.6	1.3	1.2	2.96

It will be noticed that the percentage both of nitrogen and phosphoric acid is greater in the manure left without kainite. The weight, however, was much less. Calculation showed the two lots of manure to contain plant food as follows: —

	Nitrogen. Pounds.	Phosphoric Acid. Pounds.	Potash. Pounds.
With kainite..............	.86	.80	1.96
Without kainite..............	.39	.83	.31

It will be noticed that the manure to which kainite had been added contained practically the same phosphoric acid, much more potash (of course because potash has been supplied in the kainite), and more than double the quantity of nitrogen. This experiment, it is true, is upon a small scale but similar results might readily be obtained in handling the manure from large flocks, and the saving which might possibly be made by the use of the kainite would be very important.

315. *What not to mix with poultry manure* — There is perhaps no mistake which is more frequently made than that of mixing ashes with poultry manure. Ashes contain a large amount of alkalies and these are very active in increasing the extent to which ammonia formed in such manures passes off into the air. Ashes may be used in the field or garden in connection with poultry manures, for they furnish potash in which such

manures are deficient, but to mix ashes with poultry manures as they are collected is a great mistake. Coal ashes, though containing less alkalies than wood ashes, also have a tendency to somewhat increase the loss of ammonia and they should not be mixed with the accumulating poultry manure. Lime should never be used, for this, like the ashes, helps to increase loss of ammonia.

316. *Composting with muck or peat* — If a supply of dry muck or fine, dry peat can be obtained its use in connection with poultry manures is strongly to be recommended. At the foundation of the heap put down a layer an inch or two in thickness and whenever fresh manure is added cover lightly with fine, dry muck or peat. If these materials can be liberally used they will greatly facilitate bringing the manure into good mechanical condition and will for the most part prevent loss of ammonia, although it is believed that even where they are used the addition of some kainite as well is advisable.

317. *Methods of using poultry manures* — Poultry manures, being concentrated and quick acting, are especially adapted for use in the hill or drill. As a rule an effort should be made to bring them into a finely divided mechanical condition facilitating thin and even spreading. It should be remembered that if they have been well kept and are not largely diluted by mixture with earth of some kind, poultry manures are sufficiently strong to injure seeds or roots with which large quantities come in contact. They may "*burn*" the plants. Poultry manures, therefore, should always be made fine and thinly spread.

XLIX — MISCELLANEOUS MANURIAL SUBSTANCES.

318. *What night-soil is* — The term night-soil is used among English speaking people to designate human excrements, this name being applied because the material which collects in cities and towns is so often handled during the night. It has been estimated that the excrements of a single individual during the year will contain about 11 pounds of nitrogen, and about 2½ pounds each of phosphoric acid and potash. The percentage composition according to Wolff is: Nitrogen .7 per cent., phosphoric acid

.26 per cent., and potash .21 per cent. As compared with farmyard manures night-soil, therefore, is relatively very rich in nitrogen. The enormous waste consequent upon the washing of the human excrements in our cities and large towns through the sewers into rivers or into the sea has been frequently dwelt upon by writers in all countries. It should be remembered, however, that in the case of our cities and large towns the disposal of human excrements is wholly a sanitary question and the fact appears to be that no practical method which is economically successful has been perfected for utilizing them for agricultural purposes. In different cities of the world, quite extensively in Europe, and to a less extent in our own country, human excreta have been collected and manufactured into a dry fertilizer known as poudrette. The process of manufacture, however, is attended with very disagreeable features, possibly dangerous, or at least a nuisance to the public health, and in most methods which have thus far been tried there has been great loss in the manurial value of the material during the process of manufacture. A considerable share of the nitrogen escapes into the air in the form of ammonia in most of the processes which have been tried. At the present time poudrette is not of practical consequence as a manure or fertilizer in the United States. The night-soil produced in the rural districts or in smaller towns may sometimes be used with profit on near-by farms or gardens. The most practical method appears to be to take the material to the farm and to compost with loam, muck, or peat.

319. *Animal carcasses* — The idea appears to be not uncommon that when an animal upon the farm is killed by accident or dies as a consequence of disease not contagious, it will be possible to work the carcass into valuable manure. The fact appears to be that the expense involved is so great that as a rule it will not pay to attempt to utilize such carcasses for this purpose. In many localities they can be disposed of to men who will take them to rendering establishments, where the fat and glue are extracted, and the flesh and bones both cooked or softened by steam heat under pressure, and then all ground into a fine, dry fertilizer.

320. *Muck and peat* — The words muck and peat appear to be some-

what loosely used by many. This is doubtless a consequence of the fact that there is no very well-defined dividing line between the two. These names are used to designate the material consisting largely of partially decayed vegetable matter which accumulates in swamps, marshes, or shallow ponds (86). True peat, it will be remembered, is a fuel, and should not be considered under manures. Muck, however, is sometimes quite peaty, *i. e.*, consists almost exclusively of only partially decayed vegetable matter, and such muck may have great value as a manure.

321. *Composition* — Muck and peat are composed largely of humus, though if impure the proportion of fine earth may be considerable. Humus contains nitrogen, and, as a rule, a number of organic acids and other organic compounds containing carbon, hydrogen, and oxygen. These organic acids are of no direct value as plant food. They are, indeed, if present in large quantities, injurious to plant life unless they are combined with a base. A large proportion of such acids in humus is likely to enter into combination with ammonia when muck or peat are exposed to the action of the air. Muck and peat contain considerable phosphoric acid and potash, but the percentages of these are too small to make these constituents of much importance. The only plant food element which is present in very considerable amounts is nitrogen. The percentage of this, however, varies widely. An investigation made by Dr. Johnson of Connecticut showed a variation of from a little more than ½ of 1 per cent. to a little more than 4 per cent., while Dr. Goessmann of Amherst has found a variation in muck of from about ⅛ of 1 per cent. to 2½ per cent. The average percentage of nitrogen in air-dry muck according to Johnson is 1½ per cent. Goessmann reports the average in moist muck as about ¾ of 1 per cent. The fact that variation is so wide makes it evident that before much expense is incurred in getting out muck or peat for use as manure, it will be expedient to have it analyzed. If of the better type it may richly repay the cost of handling, but, on the other hand, it may be so poor that no profit from its use can be expected.

322. *Benefits following the use of muck*—First, muck, as is evident from the preceding paragraph, if of good quality, may supply a large amount

of nitrogen. This nitrogen is not immediately available, but by exposure of the muck to the action of the air, or after application to the soil, it may become available within a moderate time. Second, these manures carry a large quantity of humus to the soil. This may be of much value, especially in the case of the lighter soils. Third, as the vegetable matter in muck or peat decays, a considerable amount of carbonic acid is formed, and this may prove useful in increasing the solubility of valuable constituents found in the soil (21).

323. *Method of using* — These materials should be dug out of the beds in which they exist during the dryest season of the year, and thrown into heaps where they should be allowed to dry. As a rule it is best to allow muck to remain in such heaps for a year or more before attempting to use it, as the long exposure to air is highly beneficial. Such exposure usually leads to the destruction of injurious acids which fresh muck or peat may contain. In other words, it sweetens the material. It also, of course, greatly decreases the bulk and weight, and it increases the availability of the nitrogen present.

324. *Composting muck or peat* — To facilitate those changes in muck or peat which are desirable, before it is used it is often expedient to compost it, and, among different mixtures which are recommended, the following seem to be likely to be most useful: —

12 bu.	wood ashes	to 100 bu.	of peat	(one cord).		
20 "	leached "	" 100 "	"	"		
10 "	quicklime	" 100 "	"	"		
20 "	gas lime	" 100 "	"	"		

325. *Leaf mould* — A more or less decayed accumulation of leaves in forests is sometimes collected for use as manure. Its collection is usually costly, and results in some injury to the forest. For these reasons, although leaf mould has considerable value, it is seldom that it will pay to collect and use it. The leaves of our forest trees are relatively rich in nitrogen, and contain only moderate amounts of phosphoric acid and potash. The average composition of a number of different varieties is reported as: nitrogen, 1 per cent.; phosphoric acid, 0.17 per cent.; potash, 0.26 per cent. It

will seem, therefore, that such leaves contain in the green weight about twice the quantity of nitrogen and one-half the quantity of phosphoric acid and potash contained in average farmyard manure. The nitrogen is, of course, the most valuable constituent. It is not known what proportion of the nitrogen found in leaf mould and substances of similar nature is available, but it is certain that they act rather slowly. Storer says: "Leaves ferment slowly. In their fermentation a large amount of humic acid is formed, and this seriously lessens their value for manure." If used at all it seems probable that leaf mould can be best utilized in composts or as a foundation for manure in yards, pens, etc.

326. *Refuse vegetable substances* — On every farm there is likely to be a larger or smaller quantity of coarse refuse vegetable materials such as leaves, ferns, straw, swamp grass, weeds, tops, and leaves of crops, etc. All these materials have some value as manure but most of them are generally best utilized as bedding. In some cases, however, the material is not of a character to make good bedding. When this is the case it should be added to the compost heap. The use of weeds, either as bedding or in composts, may not as a rule be advisable, on account of the danger that they will carry weeds to the field where the manure or compost is used. Weed seeds would not be entirely destroyed by the fermentation which goes on in the compost heap. If, then, a quantity of weeds has been suffered to ripen seeds it will usually be best to burn them. The writer has met one very successful farmer, however, who did not hesitate to use weeds as manure even when they carried ripe seeds in abundance; but his method of using them was very peculiar. He spread them as top-dressing on permanent mowings and his results indicated that the seeds of the weeds ordinarily found in cultivated fields do no harm in such mowings. The grass stifles and chokes out such weeds as may start. There are cases, it should be further pointed out, when the use of the leaves and tops of crops in compost heaps would be inadvisable. Should the crop have been badly affected with disease, such for example as blight in the case of potatoes, or smut in the case of onions, it would be a very mistaken policy to attempt to utilize such materials as manure, for the diseased tops would contain the

germs of the disease from which the crop suffered and these germs would be carried with the manure to the fields, where succeeding crops of the same kind would be likely to become affected by the same disease. It is true, indeed, that if a compost containing diseased material from one crop be used to manure a crop of a different kind there may be no bad consequences. The germs of the fungus which causes potato blight, for example, will do no harm to a crop of corn. The germs of the fungus which causes onion smut can do no harm to a crop of potatoes. But, since farmers usually rotate their crops, and since the germs of some plant diseases can live in the soil for several years, it seems on the whole best not to attempt to utilize the diseased tops or leaves for manure. It will be safer to destroy them by means of fire. The collection of refuse materials of the kinds under consideration is advisable even although they be not used for manure, because it so much improves the appearance of the farm and lessens the amount of injury to crops from insects and disease. Vegetable rubbish, if allowed to collect in fence corners, along hedge rows, or about buildings, proves a fruitful source of plant disease and affords a hiding place for insects. Such materials, then, should be collected, destroyed by fire or by burying deeply, if dangerous, either because of the presence of seeds or the germs of disease; or, if not dangerous, added to the compost heap or used as a foundation for manures in yards, pens, etc.

327. *Composts* — A mixture of materials, either of vegetable or animal origin, which is put into a heap to be rotted for manure is a compost. The materials which may be used in a compost are too numerous to mention. All coarse or refractory manures and vegetable and animal substances may be used, and with such materials ashes, lime, plaster, and kainite may frequently be mixed with advantage. The ashes and the lime will promote the rotting of the coarser materials, while plaster and kainite may prove useful in preventing loss of ammonia. The addition of ashes or kainite will, of course, greatly enrich the compost in potash and thus add directly to the value of the manure. Among materials most likely to be available for use in making composts may be mentioned: animal carcasses, fish, feathers, potato tops, chaff, weeds of all kinds, human excrements, vege-

table rubbish of all sorts from yards, materials from private and public roadways, ditch cleanings, peat, muck, urine, building refuse such as mortar, plaster, ashes, brewers' grains, and wool waste. Where any considerable quantity of materials which naturally decay very slowly is put into the compost it will be absolutely essential to use with them something which will hasten decomposition, such as lime or ashes.

328. *Directions for making a compost* — Make a foundation of earthy material such as sods, loam, muck, ditch cleanings, or street sweepings. Then put in other available materials in layers, not forgetting to sprinkle in lime or ashes if these materials are of a kind which rot slowly, and after the heap is completed cover with earth. If the materials put into the heap are very rich in nitrogen and quick to decay, as for example the flesh of dead animals or fish, then kainite should not be forgotten, as this will prevent loss. The breadth of the pile should be about six or seven feet, the height three or four feet. The top should be rather flat. When the pile is completed it should be wet thoroughly with urine if that is available, if not with water. After about two months the pile should be turned over, the materials thoroughly mixed, and if it has become dry it may with advantage be wet again with urine or water. If the materials are very rich in nitrogen it is an advantage to put in additional kainite or superphosphate at the time of working over. The fineness of the material and the availability of its constituents for plant food may be still further increased by working over a second time, but the cost of labor in this country is so great that it is not believed that this will usually be profitable. A well-made compost is rich in all the elements of plant food in readily available condition, and it is so fine that it can be used for any of the garden crops.

L — SEA MANURES.

329. Along some portions of the North Atlantic seaboard, sea manures are of much importance. There are numerous species of marine algæ which are valuable as manure. Among those which are most important and which are most generally employed are ribbon weed, broad weed or kelp, round-stalked rockweed, and flat-stalked rockweed. These all grow on

rocks near or on the shore. Besides these there is another salt water plant — eelgrass or seaweed — which grows on the muddy or sandy bottoms in shallow salt or brackish waters, which is of considerable value as manure, although often used in the first instance as a mulch or for bedding.

330. *Composition of sea manures* — Investigation has disclosed the fact that the various plants which are valuable as sea manures vary in composition at different seasons. The table gives the average of several analyses made at the Rhode Island Experiment Station. The figures of the table, however, relate to the perfectly clean, sand-free specimens of the species named. The sea manure which is washed up upon our beaches is almost always a mixture of many species with more or less sand. Such material would, of course, be poorer than the results of the Rhode Island analyses would indicate.

COMPOSITION OF SEA MANURES.

	Water. Per Cent.	Nitrogen. Per Cent.	Phosphoric Acid. Per Cent.	Potash. Per Cent.
Kelp	87.99	0.17	0.05	0.16
Broad kelp	88.50	0.23	0.06	0.21
Dulse	86.25	0.37	0.09	0.07
Round-stalked rockweed	77.26	0.24	0.08	0.64
Flat-stalked rockweed	76.55	0.38	0.12	0.65
Eelgrass (seaweed)	81.19	0.35	0.07	0.32

For the purpose of comparison, the following table, which shows the number of pounds of plant food constituents in one ton of the material, has been calculated: —

CONTAINED IN ONE TON.

	Nitrogen. Pounds.	Phosphoric Acid. Pounds.	Potash. Pounds.
Farmyard manure (average)	11.6	5.6	10.6
Kelp	4.6	1.2	6.2
Rockweed	4.8	1.6	12.4
Eelgrass	7.0	1.4	6.4

Comparison of the figures shown in the above table shows that the sea manures are relatively poor in phosphoric acid and rich in potash. They

contain a fair proportion of nitrogen. There can be no doubt that in very many cases some materials such as bone meal or superphosphate, which would furnish phosphoric acid, should be used with them. It will be noticed, further, that the sea manures contain less plant food in a given weight than farmyard manure. Their transportation, therefore, is very costly, and they cannot be used with advantage at any considerable distance from the shore. Six miles is usually about the extreme limit to which they can profitably be hauled.

331. *Collection and use as manure* — Under favorable conditions the rockweeds are sometimes cut direct from the rocks, but as a rule sea manures are collected only when they have been torn from the rock or bottom upon which they grow and washed up on the beaches. Sea manures washed up upon the beaches are the property of the owner of the adjoining land, for most deeds of such lands bound on the sea and the owner can claim everything down to low water mark. Where the demand for sea manures is large it is now as a rule necessary to buy the privilege of collecting, but where the agricultural population is sparse and the quantity of sea manures washed up upon the beaches is large they may still be had for the taking. Seaweed rots rather slowly and is not often used fresh as a manure. The other sea manures rot quickly and are usually applied to the fields as soon after collection as practicable. If these manures are allowed to rot in heaps they suffer serious loss. Such manures, like farmyard manure, furnish humus as well as plant food. They are adapted especially to the lighter soils though they may be safely used on all. They are especially suited to cabbages and onions. They are also regarded as excellent for grass lands, which are often top-dressed with them. They are fairly well suited for turnips and oats and they may be used for potatoes if applied to the field in the fall. If put on in the spring the salt which is abundant in sea manures is likely to injure the quality of the potatoes.

LI — FERTILIZERS.

332. *What is a fertilizer?* — A fertilizer may be defined as any material which in somewhat concentrated form contains compounds or elements

which added to the soil increase its productiveness. In American usage the word is for the most part employed to designate materials which the farmer as a rule purchases. The most essential elements of fertilizers are the same as those of manures, viz.: nitrogen, phosphoric acid, and potash. Others contained in some fertilizers which may be of considerable value are lime, magnesia, and sulfuric acid. As is the case with manures, so with fertilizers, there are some which, although they contain neither nitrogen, phosphoric acid, nor potash, nevertheless under some circumstances increase productiveness. Among such fertilizers may be named as examples common salt and sulfate of magnesia. Such fertilizers are valuable because of some special effect upon the soil, not because they furnish a needed element of food.

333. *Classification* — The various fertilizers which are of importance in the older states of the Union will be considered under the following subdivisions: —

1st. Fertilizers used chiefly as sources of nitrogen.

2d. Fertilizers used chiefly as sources of phosphoric acid.

3d. Fertilizers used chiefly as sources of potash.

4th. Complete fertilizers, *i. e.*, those containing nitrogen, phosphoric acid, and potash, supposedly, at least, in suitable proportions for use.

5th. Indirect fertilizers, *i. e.*, fertilizers usually employed, not to furnish either of the elements nitrogen, phosphoric acid, or potash, but for the sake of some special action upon the soil favorable to productiveness.

334. *Fertilizers used chiefly as sources of nitrogen* — The number of fertilizers coming under this class is very large and embraces materials coming from the most diverse sources, among which the most important are: animal substances, such as slaughter-house products and fish products; vegetable substances, for the most part by-products from certain seeds rich in oil; chemical substances, some of which occur naturally while others are manufactured; and modified animal excrements, guanos.

335. *General considerations affecting the value of nitrogen fertilizers.*

(*a*) *Animal and vegetable substances* — Fertilizers made from animal or vegetable substances, if suffered to partially rot before the material is

dried, may contain a little ammonia or ammonia-like compounds ; but most of the nitrogen contained in fertilizers made from such substances is present in the form of organic compounds such as albuminoids, etc. These compounds contain carbon, hydrogen, and oxygen as well as nitrogen. Nitrogen in this form is not directly available as plant food. The albuminoids or other similar organic nitrogen compounds must first decay and be acted upon by the ferments (bacteria) found in the soil (125). Under the influence of these agencies the nitrogen first enters into combination with hydrogen to form ammonia and later unites with oxygen to form nitric acid. It will be remembered that nitric acid in combination with some base, *i. e.*, in the form of a nitrate, is the most acceptable form in which nitrogen can be offered to plants (22). The length of time required for the change of organic nitrogen into nitrates varies widely in the different fertilizers of the class under consideration. Other things being equal, that material in which these changes take place most quickly is the most valuable. The rapidity of these changes depends for the most part upon the physical characteristics of the different materials as affecting decay, which must always be the first step. Thus, for example, blood and flesh decay rapidly, and the nitrogen in fertilizers made from them becomes available within a comparatively short time after the fertilizer is mixed with the soil. In cottonseed meal and castor pomace these changes go on somewhat more slowly and the nitrogen in these fertilizers does not become so quickly available as in fertilizers made from blood or flesh. In bones and hoof meal decay goes on more slowly still ; in horn meal and wool waste more slowly even than in bones, and in leather most slowly of all. Many of the fertilizers made from such animal and vegetable substances as are used chiefly for their nitrogen contain phosphoric acid in moderate amounts. This is true of almost all those made from slaughter-house materials and fish. The phosphoric acid in such fertilizers is derived chiefly from bones which enter into these fertilizers. The greater the proportion of bone the higher will be the percentage of phosphoric acid. It is in some cases difficult to decide whether some of these animal fertilizers should be looked upon as nitrogen fertilizers or phosphoric acid fertilizers. In some of those which will be here included

the percentage of phosphoric acid is even greater than the percentage of nitrogen in the lower grade materials. They are included, however, because the better grades bearing the same name contain more nitrogen than phosphoric acid. Those fertilizers in this class which are of vegetable origin also contain phosphoric acid and a little potash as well. Nitrogen, however, is their leading constituent and the one for which they are chiefly used. They are, therefore, included in this class. Nitrogen applied to the soil in the form of an organic compound cannot be washed out of the soil so long as it remains a part of such compound. Hence, if fertilizers from animal and vegetable substances be intelligently used there is little probability that a loss of nitrogen through leaching will take place. On the other hand, if such fertilizers be left upon the surface a part of the ammonia which is formed as they decay may escape into the air, as is also true in the case of farmyard manures.

(*b*) *The natural guanos* — A considerable share of the nitrogen in the natural guanos is present in the form of ammonia and a proportion of it also as nitric acid. Nitrogen in these fertilizers, therefore, is more quickly available than in those derived from animal or vegetable substances. That portion of the nitrogen present in the form of nitric acid or nitrates is of course subject to loss through leaching.

(*c*) *Chemical substances* — In the different fertilizers coming under this class the nitrogen usually exists in combination either as ammonia or nitric acid. It will be remembered that ammonia can be fixed by soils and that it is not likely to be lost by leaching (125). Many therefore regard fertilizers in which the nitrogen exists as ammonia as the most desirable. The nitrogen is not subject to loss by leaching but it is soluble and is likely to pass rapidly through the changes which will convert it into nitric acid. When the nitrogen in a fertilizer exists in the form of nitric acid or nitrates it is subject to loss by leaching from the moment of application, as the soils have no capacity to fix nitrates by chemical means. Nitrogen in this form is immediately available and from this point of view the nitrates are highly desirable. If used intelligently, *i. e.*, in reasonable amounts at the proper season, it is not believed that there will be much loss when applied in this

form and therefore, although some hesitate to use nitrates largely, fearing loss, many regard them as the most valuable class of fertilizers.

336. *The important nitrogen fertilizers named*—The more important of the fertilizers used in the Northeastern states as sources of nitrogen are the following:—

(*a*) Derived from animal sources: Dried blood, meat meal, azotin and ammonite, tankage, hoof meal, horn meal, wool and hair waste, leather meal, dry ground fish, and king crab.

(*b*) Derived from vegetable materials: Cottonseed meal and castor pomace.

(*c*) Modified animal excrements: Peruvian guano, bat guano.

(*d*) Chemical substances: Sulfate of ammonia, nitrate of soda, nitrate of potash, nitrate of lime and calcium cyanamide or lime nitrogen.

337. *Dried blood*—The dried blood which is used as a fertilizer comes from large slaughtering establishments. The only manufacturing process to which it is subjected is drying. It is rapidly dried by artificial heat. According to the degree of heat used, the manufactured product may be either red or black. The red blood is produced by the careful drying of fresh blood at a temperature not above that of boiling water, so that there is no charring. Dark or black blood is dried at a higher temperature. It is somewhat leathery in character. Red blood decays very rapidly and is a quickly available fertilizer. It is quite uniform in composition. Black blood is less uniform and does not decay as quickly as the red, so that it is less available. As a rule neither grade of blood is kept entirely pure. As put upon the market it is likely to contain some hairs and impurities of other kinds, and from the fact that it sometimes contains considerable phosphoric acid it would appear that some bone is worked up with it. The large fertilizer dealers often offer three different grades of dried blood. The best blood contains from about 10.5 to 12.5 per cent. of nitrogen; the lowest grade may contain only from 7 to 9 per cent. Good dried blood is the most concentrated of the organic nitrogen fertilizers. It is extensively used in the manufacture of mixed fertilizers and is often a good material for the farmer to buy and use.

338. *Dried meat meal* — This material comes from rendering establishments where the different portions of dead animals are utilized and from beef extract factories. It is also known by such names as azotin and ammonite, but these various names may designate practically the same substances. When pure, meat meal may contain from 13 to 14 per cent. of nitrogen. In most cases, however, some bone is worked up with it. This lowers the per cent. of nitrogen and adds some phosphoric acid. The manufacturing process consists, first, in separating the fat; second, drying by artificial heat; and third, grinding. The more perfectly the fat is extracted from the material worked up into this fertilizer the more valuable it will be, for fat has no manurial value. Meat meal, if derived chiefly from meat and not too largely from bone, decays rapidly in the soil and is therefore a fairly available fertilizer.

339. *Tankage* — Tankage consists of the dried animal wastes from large slaughtering establishments. It is variable in its composition, owing to the fact that there may be considerable variation in the proportion of the different classes of materials which are worked into it. As commonly made it may include offal, small bones, tendons, waste flesh, and hair. Such of these materials as contain fat are rendered for the extraction of the fat; all is then highly heated by steam and, when dry, ground into a fine meal. Tankage always contains considerable phosphoric acid as well as nitrogen, and the percentages of the two vary. As the nitrogen decreases the phosphoric acid usually increases, and the opposite is also true. The larger the proportion of bone entering into tankage, the higher the percentage in the phosphoric acid and the more slowly will the material become available. The three grades of tankage offered by one of our Eastern manufacturing companies at the present time have the following composition: —

1st. Nitrogen, from 5.6 to 6 per cent.; phosphoric acid, from 11 to 13 per cent.

2d. Nitrogen, from 6.6 to 7.5 per cent.; phosphoric acid, from 9 to 11 per cent.

3d. Nitrogen, from 7.4 to 8.3 per cent.; phosphoric acid, from 7 to 9 per cent.

Tankage having the composition of the last grade is much more valuable than that containing less nitrogen. It will prove a quicker acting fertilizer as a larger share of its constituents come from the fleshy waste products of the animal. This portion will decay rather quickly, while that part of the tankage which comes from bone must decay more slowly. The phosphoric acid in the tankage has about the same value as that in bone meal, although it may become available somewhat more quickly since it comes from the smaller and softer bones (358).

340. *Hoof meal*—Hoof meal is a product which comes from glue factories, button factories, etc. It is made by grinding either the entire hoof or, in case of that which comes from button factories, the chips, shavings, etc., into a fine meal. It is quite uniform in its composition, containing on the average about 12 per cent. of nitrogen. Nitrogen in this form requires a somewhat longer time to become available than does that in blood, since the hoof meal does not decay as quickly as blood. Experiments indicate that nitrogen from this source acts with about the same quickness as the nitrogen in tankage.

341. *Horn meal*—The factories in which combs, buttons, etc., are made from horn furnish chips and shavings which are finely ground and put upon the market as a fertilizer. Horn meal is fairly uniform in composition, containing from about 10 to 12 per cent. of nitrogen. It is, however, very slow to decay and farmers cannot be advised to use it in the raw form. The fertilizer manufacturer sometimes treats horn meal with acid and this makes it more quickly available. In this form it doubtless is included in some of the mixed fertilizers which are put upon the market.

342. *Wool and hair waste*—Waste wool or hair, usually considerably mixed with dirt and dust, are sometimes put upon the market as a fertilizer. Pure hair and wool are rich in nitrogen, of which they may contain from 15 to 16 per cent. This material, however, decays very slowly. Moreover, owing to the fact that dirt of various kinds is usually included with such waste it varies very widely in composition. For these reasons the farmer cannot be advised to employ such materials as a fertilizer unless they can be obtained at very low cost.

343. *Leather meal* — The smaller scraps and chips from all branches of leather manufacture are collected and ground into a meal which is sometimes offered as a fertilizer or incorporated with mixed fertilizers. Leather is fairly rich in nitrogen, of which it may contain from 5 to 8 per cent., but it is altogether too slow in decaying to make its use by the farmer advisable. Some manufacturers have roasted leather with the idea of increasing the availability of its nitrogen, but such experiments as have been tried indicate that no great amount of improvement results from this treatment. There is considerable evidence to show that if leather meal be treated with sulfuric acid it is rendered much more available, but the farmer cannot be advised to undertake this treatment for himself. Leather meal, therefore, is not a fertilizer which he can be advised to purchase. The fertilizer maker may employ it in the production of mixed goods, but any considerable proportion of leather meal in a fertilizer must be regarded as undesirable on account of the slow availability of nitrogen in this form.

344. *Dry ground fish, or fish guanos* — The greater part of the fish fertilizers upon our markets are made from the menhaden, a species of herring. These fish are taken in nets, steamed, and subjected to hydraulic pressure for the extraction of the oil; the pomace is then broken up, rapidly dried, and ground. Fish fertilizers made in this way will contain nitrogen, from 8.5 to 11 per cent., phosphoric acid, from 3.8 to 5 per cent. Some of the fish fertilizers upon the market, however, come from other sources, such as curing and canning establishments, and markets. The material from these sources consists chiefly of the heads, fins, and perhaps the larger bones, scales, etc. These materials should be rendered, dried, and ground. Containing a larger proportion of bones and less flesh than the fertilizer made from menhaden, the fish fertilizers from these sources are rich in phosphoric acid and poorer in nitrogen than those having the first origin. One of the large manufacturing firms usually offers three grades of fish: 1st, nitrogen, from 5 to 5.5 per cent.; phosphoric acid, from 5.5 to 6.5 per cent. 2d, nitrogen, from 6.5 to 8.2 per cent.; phosphoric acid, from 4.5 to 5.5 per cent. 3d, nitrogen, from 8.2 to 10 per cent.; phosphoric acid, from 3.7 to 4.6 per cent. The nitrogen in fertilizers of this class becomes available in

about the same length of time as that in tankage, and its degree of availability varies in accordance with the same conditions, *i. e.*; the more bone or the higher the percentage of phosphoric acid, the more slowly a fish fertilizer will become available. The phosphoric acid in fish fertilizers has about the same value as in bone meal. Fish fertilizers are valuable for the farmer's use and are also considerably employed in the production of mixed goods.

345. *King crab* — According to Voorhees this species of crab is taken in considerable quantities along the Atlantic coast. It is rapidly dried, ground fine, and used in the production of mixed fertilizers. It contains on the average about 10 per cent. nitrogen, which is highly available. This material is far less important than dry ground fish and is not generally offered by fertilizer dealers, being apparently entirely used in the making of mixed fertilizers.

346. *Cottonseed meal* — Cottonseed meal is generally well known as a cattle food and its most profitable use, where circumstances render it possible, is first as a feed. It will greatly enrich manures made from animals consuming it (290,*a*). Cottonseed meal, however, is so abundant and so cheap in many parts of our country that it is not infrequently directly employed as a fertilizer. It is particularly in favor among tobacco growers, as its influence on the quality of the tobacco leaf is very favorable. In the preparation of cottonseed meal the seed is first decorticated, then ground, and lastly the oil extracted either by pressure or by chemical means. Well manufactured cottonseed meal contains from about 6 to 7 per cent. of nitrogen, 1.2 to 2 per cent. of phosphoric acid, and 1.7 per cent. potash. The more perfectly the fat is extracted in the process of manufacture the more valuable is the fertilizer for reasons already given (338). The nitrogen in cottonseed meal is fairly available, as this material decays in the soil rather quickly. Nitrogen in this form should be ranked about with that in good fish and tankage. Cottonseed meal which has been so damaged as to be unfit to feed can sometimes be purchased at a price considerably lower than that of the sound article, and it may be equally valuable as a fertilizer.

347. *Castor pomace* — This is the by-product from the manufacture of

oil from castor beans. It is put upon the market in the form of a fine, dry meal. This meal is unfit to feed and its only use is as a fertilizer. It has about the same composition as cottonseed meal, containing about 6 per cent. nitrogen, 2 per cent. phosphoric acid, and 1.1 per cent. potash. The more perfectly the fat is extracted the more valuable is the fertilizer (338). Nitrogen from this source becomes available in about the same length of time as that in cottonseed meal.

348. *Peruvian and other guanos* — The accumulated droppings of fish-eating fowls, more or less mixed with the dead bodies of these fowls and perhaps with remnants of fish, etc., become converted in the course of time into a somewhat permanent form well suited for use as fertilizer. The most important source of this material ever found in any part of the world was a group of islands lying off the western coast of Peru in a locality with little or no rain. If the production of a rainless country, such guanos are rich in nitrogen; if from localities with rain, they contain less nitrogen, as a portion will be washed out with the rain water which soaks through the accumulating material. All guanos of this class contain phosphoric acid and potash as well as nitrogen. Peruvian guano was formerly abundant and important, but the supply at the present time is nearly exhausted, and although offered by some of our dealers this fertilizer cannot now be considered as of much importance. When of good quality it is one of the most valuable of fertilizers; but the better material has been very largely exhausted and the composition of the guanos now offered is very variable.

349. *Bat guano* — In warm climates in some parts of the world bats have been so exceedingly numerous that their droppings have accumulated in large amounts in caves to which these animals resort for rest and hiding by day. Bat guano is fine, dry, and well adapted for distribution. The sample from Texas analyzed in the Massachusetts Experiment Station contained about 6.5 per cent. nitrogen, 3.7 per cent. phosphoric acid, and 1.3 per cent. potash. This fertilizer is not sufficiently abundant to have become of much importance in the Northeastern states.

350. *Sulfate of ammonia* — Sulfate of ammonia is a by-product from

many manufacturing processes. It may be abundantly produced in the manufacture of bone charcoal, illuminating gas, or coke. It is the most concentrated of all the nitrogen fertilizers, usually containing no less than 20 per cent. of nitrogen. It contains absolutely no phosphoric acid or potash. The sulfate of ammonia offered as a fertilizer is usually fine and dry. It does not attract moisture from the air to any considerable extent, hence it is not as likely to become moist and lumpy as are some of the other fertilizers. Its good mechanical condition, moreover, makes it an easy material to spread and well adapted to mixing with other materials for the production of mixed fertilizers. Nitrogen in this form becomes available within a comparatively short time, although it is behind the nitrates in this respect. Before it becomes available the nitrogen in it must be acted upon by nitric acid ferments (133), and the action of these bacteria appears to be greatly favored by the presence of abundance of lime or other alkalies in a soil. In soil which contains free acid, or which in farmer's language is "sour," sulfate of ammonia gives very unsatisfactory results. If such soil is given a heavy application of lime, sulfate of ammonia gives far better results. The results of numerous experiments in the Massachusetts Experiment Station indicate further that sulfate of ammonia should not be used in connection with fertilizers which contain chlorids, such for example as muriate of potash or kainite. If so used there is likely to be an interchange of acids and bases, the sulfuric acid, which was a part of the sulfate of ammonia, leaves the ammonia and combines with potash or soda, and the chlorin combines with the ammonia forming chlorid of ammonia. This compound is highly injurious to plants.

Unlimed. Limed.

FIG. 60. Broom corn; both manured alike with potash, phosphate, and sulfate of ammonia. *Courtesy of R. I. Exp. Station.*

351. *Nitrate of soda* — The nitrate of soda which is so extensively used in different parts of the world as a fertilizer all comes from South America,

chiefly from a locality which is now entirely rainless and which lies not far from the west coast of Chili. The raw material consists of large crystalline masses of nitrate of soda more or less mixed with sand or earth. This raw material is known as caliche. This material is gathered, broken up, the soluble nitrate dissolved in hot water, the mixture of earth and solution filtered to separate the latter, and then the solution is heated and the salt re-crystallized. The product obtained in this way is not chemically changed; it is simply freed from the greater part of the impurities (sand, etc.) mixed with it in the caliche. This process does not render the salt absolutely pure, but the business is carefully carried on and the commercial nitrate of soda offered as a fertilizer runs very even in composition, being from 95 to 98 per cent. pure, *i. e.*, containing only from 2 to 5 per cent. of impurities and from about 14.25 to 16 per cent. of actual nitrogen. The commercial product, on account of its resemblance to ordinary saltpeter and because of the locality from which it comes, is often spoken of as Chili saltpeter. Chili saltpeter ranks next to sulfate of ammonia among different nitrogen fertilizers in the average percentage of nitrogen it contains. It is a concentrated nitrogen fertilizer, and, as has been pointed out in other connections, nitrates are the most available and the quickest acting compounds which contain nitrogen (335). Attention is here called again to the fact that nitrate of soda is not chemically absorbed by soils (125). The only way in which nitrate of soda is at all fixed in soils is by physical means, and these are strongest in the soils containing considerable clay and fine silt (114). The danger that nitrate of soda, therefore, may be carried out of the soil whenever water soaks through it in large quantities is comparatively great, especially in the soils which are of a coarse, open character. Nitrate of soda is quickly soluble and it diffuses through the soil rapidly (136). There is no nitrogen fertilizer, therefore, which will benefit the crop so immediately. This fact, in connection with what has been said concerning possible loss, indicates the proper method of using nitrate of soda. It should be employed when an immediate supply of nitrogen to the plant is wanted, and must be used with a view to feeding the plant directly and not for the purpose of enriching the soil in nitrogen. It must be used with

the greater caution the lighter and more open the soil. If it is to be employed in large amounts it should be divided and put on at different times, say one-third when the seed is planted or soon after it comes up, one-third when the plant is about one-fourth grown, and the balance when it is about one-half grown. It is believed that on all except soils of the most open and porous character, nitrate of soda may be used in quantities up to about 200 pounds per acre in a single application at seedtime without much danger of loss.

No Nitrogen. Sul. of Am. Leather. Blood. Nit. of Soda.

FIG. 61. BARLEY (*Unlimed*). All manured alike with potash and phosphoric acid. Like quantities of nitrogen were applied in each case. *By courtesy of Rhode Island Experiment Station.*

352. *Nitrate of potash* — Nitrate of potash, or common saltpeter, is a manufactured product very similar in its general characteristics to nitrate of soda. The nitrate of soda, however, contains only one of the essential elements of plant food,— nitrogen, while nitrate of potash contains two, nitrogen and potash. The percentage of nitrogen is about 13 or 14 ; of potash, about 46. In the nitrate of potash, as in the nitrate of soda, the nitrogen is immediately available. Nitrate of potash, however, dissolves and diffuses through the soil somewhat more slowly than nitrate of soda, so that its action is not likely to be quite so prompt. Nitrate of potash has so many

uses outside of agriculture, that, notwithstanding the fact that it would rank as a very concentrated and valuable fertilizer if available, it is not often employed, since it costs more than the farmer can afford to pay.

352a. *Nitrate of lime*—Within the last few years methods have been perfected whereby atmospheric nitrogen under the influence of powerful electric currents is made to combine with lime to form a nitrate. The nitrate of lime contains about 9 to 10 per cent. of nitrogen. Such experiments as have been tried indicate that nitrogen in this form will prove promptly available. In rapidity of action it appears to compare favorably with nitrate of soda, and it seems probable that the large amount of lime supplied by this fertilizer will also prove valuable in soils where this compound is naturally deficient.

352b. *Lime nitrogen*—The term lime nitrogen is used to designate a chemical compound known as calcium cyanamid. This new compound

No Nitrogen. No Nitrogen. Sul. of Am. Leather. Blood. Nit. of Soda.

FIG. 62. BARLEY (*Limed, excepting the first lot at the left*). All manured alike with potash and phosphoric acid. The quantities of nitrogen were identical in each instance and the same as in Fig. 61.

By courtesy of Rhode Island Experiment Station.

contains about 18 to 19 per cent. of nitrogen. It is a manufactured product, produced under the influence of powerful electric currents whereby nitrogen obtained by fractional distillation from liquid air is made to combine with calcium carbid. As lime nitrogen contains about twice the percentage of nitrogen contained in nitrate of lime, it is likely to prove more useful in localities remote from the place of manufacture, as it can better bear the necessary freight charges. Lime nitrogen appears to be quite promptly available. It is regarded as desirable to apply this compound some little time previous to planting seeds, as some of its constituents when first applied are injurious to vegetation. When mixed with the soil, however, the injurious compounds of lime nitrogen are soon rendered harmless.

353. *Relative availability and value of the nitrogen fertilizers* — The important facts which must be kept in mind in determining the value of nitrogen fertilizers for different purposes may be briefly summed up as follows: —

The nitrates, Chili saltpeter and the common saltpeter are soluble, they diffuse through the soil quite quickly, they are ready to feed crops at once. The nitrogen, however, is subject to loss, being held simply by physical means, and not entering into insoluble combinations.

The sulfate of ammonia is soluble. It diffuses through the soil quite rapidly, it is not immediately available, it must nitrify before the plant can use it. This change, however, requires only a short time in summer weather, provided the soil is not sour. If sour, lime must be added in order to favor more rapid nitrification. The ammonia of this fertilizer is chemically fixed in the soils, it is not likely to be washed out, though after nitrification the nitrogen is subject to loss. Lime nitrogen is not immediately soluble in water, but in the presence of moisture the chemical compound, calcium cyanamide, which it contains, quickly breaks up and ammonia is formed. If, therefore, lime nitrogen is used as a top dressing, there is a possibility of a loss of a portion of its nitrogen, through the escape of the ammonia into the air; but if this fertilizer is mixed with the soil, the ammonia as it is formed is likely to be fixed either by physical or chemical action. When this ammonia, as would be the case in soils containing enough lime to render them neutral or alkaline, is converted into nitric acid or nitrates, the nitrogen is subject to loss as is the case with other nitrates.

Of the organic fertilizers from animal and vegetable substances, it may be said that the nitrogen is at the start insoluble, and becomes soluble only after the substances decay, when it enters the compound ammonia. And further, before this nitrogen of the ammonia can be used by the plants it must nitrify. Those fertilizers of this class are most quickly available which, because of their physical characteristics, rot most quickly. Nitrogren fertilizers of this class may be used for the purpose of enriching the soil in nitrogen, as they are far less subject to waste than the nitrates or ammonia. The availability of fertilizers of this class is modified to some extent by the nature of the soil and the season. In the more open soils they rot rapidly, and their nitrogen becomes available more quickly. Lime hastens the availability of most of them. In warm summer weather the necessary changes go on rapidly, provided the soil contains sufficient moisture. In excessively dry seasons or very dry soils, the nitrogen of such fertilizers might not become available in season to help the crop, while the nitrogen of the nitrate of soda would become available, because it requires but little water to dissolve it. On the other hand, in an excessively wet season nitrate of soda may be largely wasted. In such a season sulfate of ammonia or one of the organic nitrogen fertilizers may give better results. Numerous experiments have been tried for the purpose of determining the relative efficiency, or, in other words, the relative increase in the crop which may be expected from the use of different nitrogen fertilizers; and European investigators, taking nitrate of soda as the standard, because its action is the best, and representing the increase in the crop which it produces by 100, rank the other nitrogen fertilizers as shown in the table: —

RELATIVE EFFICIENCY OF NITROGEN FERTILIZERS

Nitrate of soda	100
Sulfate of ammonia and Peruvian guano	83
Dried blood, horn meal, castor pomace and green manures	65
Bone meal, dry ground fish, flesh meal	53
Wool dust and stable manures	25
Leather meal	15

These results were obtained for the most part by means of experiments in jars. A series of experiments in the open field at the Massachusetts Ex-

periment Station has been in progress (1910) for twenty years. The materials furnishing nitrogen which are under comparison have given yields which rank in the following order: —

Nitrate of soda,	100.00
Farmyard manure,	94.05
Dried blood,	92.34
Sulfate of ammonia,	86.47
Plots to which no nitrogen has been applied,	70.99

On the basis of increase in crop as compared with the no-nitrogen crops, the average of the 20 years shows the following relative standing:

Nitrate of soda,	100.00
Barnyard manure	79.51
Dried blood,	73.62
Sulfate of ammonia	53.36

In these experiments at Amherst the different materials used as the source of nitrogen are always applied in such quantities as to furnish precisely the same amount of nitrogen to each plot. The nitrate of soda has been used at the rate of 290 pounds per acre and the entire quantity has always been applied in spring just before planting the seed. The soil of the field where these experiments have been tried is a moderately heavy loam, and the results of the experiments certainly indicate that there can have been no considerable loss of the nitrogen applied in the form of nitrates. The reports of the Massachusetts Station call attention to the fact that during some of the years included in the experiment the crops upon the sulfate of ammonia plots have been almost absolute failures, but that the application of lime after such crops has never failed to effect great improvement. In those years following the application of lime the yield on the sulfate of ammonia plots has been fully equal to that on the plots to which nitrate of soda was applied. Numerous reports from the Rhode Island Experiment Station have called attention to the same facts. In many of the experiments at this station the sulfate of ammonia without lime has proved absolutely useless, while with lime it has given excellent crops.

354. *The selection of nitrogen fertilizers* — In determining what nitrogen-containing fertilizers are likely to give the best results, it is necessary to consider the nature of the soil and the crop which is to be grown.

(*a*) *Soil* — It follows from the statements which have been made that the more open and porous the soil and the subsoil, the greater the necessity for using nitrogen fertilizers which the soil can hold. The heavier and more

retentive the soil and the more compact the subsoil, the safer it is to depend upon the soluble and quickly-acting nitrates.

(*b*) *Crop* — For such crops as begin their growth very early in the season the immediately available nitrates are generally much superior to those fertilizers which require time to become available. Owing to the fact that nitrates tend to wash out of the soil, it usually happens that in the early spring the soil is very poor in these compounds, and since these are much the best for the crop, it will be seen that the nitrate of soda is the fertilizer best calculated to promote the rapid and luxuriant growth of all the early growing crops. Therefore, if the soil is naturally poor in nitrogen and the crop is one which has only a very short season of growth, the nitrate of soda may be the best fertilizer because it is ready to feed the crop at once. On the other hand, for crops growing chiefly after the season has become well advanced, such for example as corn, the slower-acting fertilizers may safely be used. For those which have a long period of growth or which occupy the ground permanently it is safe to depend upon the slowly-acting fertilizers.

As a rule, except for such crops as make all their growth very early and those which have a very short season for growth, it will be best to furnish nitrogen in three or more different forms of combination, a little nitrate of soda for immediate effect, some sulfate of ammonia for a little later use, and blood, fish, or tankage or cottonseed meal to carry the crop through to maturity. All these materials should be mixed and applied at the time of planting. Among crops for which the use of nitrate of soda has been found to be particularly beneficial may be named : grass, oats, and outdoor lettuce, spinach, and beets, when grown as early garden crops. It is believed that potatoes should generally receive considerable nitrate nitrogen, because the growing season is rather short ; while corn, beans, tomatoes, squashes, and other late crops may utilize the nitrogen of organic fertilizers.

LII — FERTILIZERS USED CHIEFLY AS SOURCES OF PHOSPHORIC ACID.

355. *What is a phosphate?* — All those fertilizers which are used chiefly as sources of phosphoric acid may be correctly spoken of as phosphates,

because in all of them the phosphoric acid exists in the form of a salt formed by the chemical union of the acid and a base (10). It is true, indeed, that some of the fertilizers which are used chiefly for the phosphoric acid they contain, also contain some nitrogen (335), but, notwithstanding this fact, since such fertilizers are used chiefly for the phosphoric acid, it seems appropriate to consider them phosphates. The word phosphate ought not to be used to designate any fertilizer save one which is employed chiefly for its phosphoric acid. As a matter of fact, however, farmers use the word to designate almost any kind of fertilizer. The impression appears to be general that any artificial fertilizer is a "phosphate." This inaccurate use of the word is perhaps explained by the fact that the first artificial fertilizer to be used by farmers to any considerable extent was a phosphate, and at the time when phosphates began to be used there were no special nitrogen or special potash fertilizers in use. The practice of using these is of later origin, and their introduction was gradual. Moreover, at first materials containing nitrogen and potash were almost invariably mixed with a phosphate, and the name of the fertilizer thus produced was not changed. It was still called a phosphate, although quite different from the material originally manufactured. It must be pointed out, further, that fertilizer manufacturers and dealers are in considerable measure responsible for the inaccurate use of the word "phosphate." They often manufacture and offer for sale under the name "phosphate" fertilizers which, as they contain large amounts of nitrogen and potash, would better be distinguished by some other name. Particular attention is called to these facts for the reason that in what follows the word "phosphate" is not used in the somewhat common but inaccurate sense above pointed out and explained, but simply to designate such fertilizers as are valuable chiefly or exclusively for their phosphoric acid.

356. *Classes of phosphates* — The number of phosphates, or materials used chiefly or wholly for their phosphoric acid, available for use in the United States is large, but all may be included under five classes : —

1st. Bones and materials derived from them : ground bone, both raw and steamed, bone black, and bone ash.

2d. Mineral phosphates: apatite, South Carolina rock, Florida phosphates (rock and soft), and Tennessee phosphates.

3d. Phosphatic guanos: Mona guano, etc.

4th. By-products of steel manufacture: basic slag or phosphatic slag.

5th. Manufactured phosphates, including superphosphate, acid phosphate, and dissolved phosphates.

357. *The different compounds of phosphoric acid in the various phosphates* — As has been pointed out, the acid exists in all the phosphates in the form of a compound with some base. The base with which the phosphoric acid is usually combined is lime, although in some of the mineral phosphates it may be combined in part with alumina or iron oxid. Phosphoric acid, as has been pointed out (126), forms several different compounds with lime.

(*a*) In bones and their natural products, in the rock or mineral phosphates, and in the phosphatic guanos the phosphoric acid exists in combination as three-lime phosphate.

$$\text{Graphic representation :—}\quad \left.\begin{cases}\text{Lime}\\ \text{Lime}\\ \text{Lime}\end{cases}\right\}\text{Phosphoric acid.}$$

This graphic representation indicates that three equivalents of lime are combined with one of phosphoric acid. This compound is insoluble in water or in weak acids. It is not, therefore, at first available to any considerable extent, as it becomes soluble but slowly. Such phosphates are, however, attacked by natural agencies operating in the soil (soil acids, 126; plant roots, 52, etc.,) and are gradually but slowly made available.

They are likely to become most rapidly available in soils which contain much humus, because in such soils the decay of the humus produces acids which will steal a part of the lime away from the phosphoric acid (126), thus making the latter more soluble.

(*b*) In basic slag the phosphoric acid exists in different combinations with lime and iron, but chiefly according to some authorities as a double salt of three lime phosphate and lime silicate.

$$\text{Graphic representation :—}\quad \left\{\begin{array}{l}\text{Lime}\\ \text{Lime}\\ \text{Lime}\\ \text{Lime}\end{array}\right\}\begin{array}{c}\text{Phosphoric acid}\\ \text{and}\\ \text{Silicic acid}\end{array}$$

Very little of the phosphoric acid in basic slag is soluble in water but much of it is soluble in weak acids such as may be found in soils or in the roots of plants, and it is therefore available to plants with a fair degree of rapidity.

(*c*) In the manufactured phosphates (superphosphate, dissolved phosphates, etc.) the phosphoric acid exists mostly as one-lime phosphate.

$$\text{Graphic representation :—}\quad \left\{\begin{array}{l}\text{Lime}\\ \text{Water}\\ \text{Water}\end{array}\right\}\text{Phosphoric acid.}$$

This method of indicating the nature of one-lime phosphate is intended to show that in this phosphate one equivalent of lime and two equivalents of water are combined with one phosphoric acid. The one-lime phosphate is soluble in water. When applied in this form to the soil it diffuses quite rapidly so that it becomes much better distributed than is possible in the case of a material which must be mechanically mixed with the soil. In this form phosphoric acid is promptly available.

(*d*) In most manufactured phosphates there will be found also a moderate proportion of two-lime phosphate.

$$\text{Graphic representation :—}\quad \left\{\begin{array}{l}\text{Lime}\\ \text{Lime}\\ \text{Water}\end{array}\right\}\text{Phosphoric acid.}$$

In this phosphate, as shown above, two equivalents of lime and one of water are combined with one of phosphoric acid. The phosphoric acid which exists in this form is known to fertilizer manufacturers as reverted phosphoric acid (126). Reverted phosphoric acid is not soluble in pure water but it is dissolved by weak acids such as are found in the soil and in the plant roots. It is therefore considered to be available. It is inferior, however, in the promptness of its action to the one-lime phosphate because not being so readily soluble, it does not diffuse throughout the soil.

(*e*) It will be remembered that phosphoric acid, even in its soluble

compounds, is not much liable to loss from. soils by leaching. Though soluble when applied the phosphoric acid soon takes up more of some base (lime, alumina, or iron oxid) and becomes fixed (126). Only in soils of the most open character and deficient in lime, and when applied in very large quantities, is soluble phosphoric acid likely to be lost by leaching ; and even then not in large amounts. It has been shown, however, that heavy applications of chlorids (common salt or kainite) increase the danger of loss of phosphoric acid by leaching.

LIII — THE NATURE AND GENERAL COMPOSITION OF THE DIFFERENT PHOSPHATES.

358. *Bone, and materials derived from bone.*

(*a*) *Raw bone meal or ground bone* — This article is made by grinding raw bones, and the finer the grinding is done the better. This is because when the material is fine it can be more readily acted upon by the agencies which render the valuable constituents available. For the manufacture of raw bone meal it is desirable that those bones which are as free from fat as possible should be selected. This is because the presence of fat in the bones makes it difficult to grind them fine and, moreover, hinders decay. The bones from different parts of the body differ somewhat in composition, but as a rule they contain about one-third organic matter which contains nitrogen, and two-thirds mineral matter which is chiefly three-lime phosphate. Pure ground bone should contain about 4 per cent. nitrogen and 22 per cent. phosphoric acid, the latter in the form of three-lime phosphate. Both the nitrogen and the phosphoric acid, as will be understood from what has preceded, must be rather slowly available. Some European investigators believe that their experiments prove that the phosphoric acid in raw bone is nearly valueless on account of the extreme slowness with which it becomes available. This view, however, is not generally regarded even in Europe to be correct, while in the United States numerous experiments show that raw bone meal may often be profitably employed. It is reported by the Massachusetts Experiment Station that land which for seven or eight years has been manured continually with bone meal and a fertilizer supplying

potash, has during all that time given excellent crops of all the leading kinds which are cultivated in that state; and that at the present time (1901) the yield on this land is excellent, amounting in the case of such crops as silage corn to as much as from 20 to 25 tons, and in the case of potatoes to as much as from 200 to 250 bushels per acre. Some of the experiments in this station, moreover, indicate that, contrary to the general belief, the fine ground raw bone is at least equally as available as the fine ground steamed bone.

FIG. 63. This plot has been for six years manured as shown by the label.
By courtesy of Hatch Experiment Station.

(*b*) *Steamed or boiled bone* — The larger proportion of the bone used for meal is first steamed or boiled for the purpose of extracting the fat, and it may be the nitrogenous matter. Both the fat and the nitrogen compounds are valuable for other purposes — the fat for soap, etc., the nitrogen for glue and gelatin. The extraction of the fat, as will be evident from what has preceded, must be considered an advantage. The extraction of the nitrogen, on the other hand, of course lowers the value of the bone. Ground steamed bone contains more phosphoric acid and less nitrogen than the raw bone, according as the extractive process has been more or less perfectly carried out. Bone which has been used for making glue will not,

as a rule, contain more than about 1½ per cent. of nitrogen, and the phosphoric acid usually varies from about 28 to 30 per cent. Steaming, particularly at high pressure, improves the mechanical condition of bone. It destroys the original tough, bony structure, and makes the material soft and crumbly. Such bone can readily be made finer than raw bone, and it has commonly been held that owing to this difference, and to the further fact that such bone is free from fat, phosphoric acid in steamed bone would act more promptly than that in raw bone, but in the light of some recent experiments it appears doubtful whether this is the case. Certain it is that steamed bone acts rather slowly. Much of the phosphoric acid in it is in the three-lime form, although there may be a small proportion of reverted or two-lime phosphate. Steamed bone meal, however, is much used by farmers, and can be recommended for slow growing crops and for soil improvement. It is much used in mixed fertilizers.

(*c*) *Extracted bone* — The fat in raw bones is sometimes chemically extracted by the use of benzine or some other material which readily dissolves fats. Under this treatment the fat is much more completely taken out of the bone than is possible by rendering. This treatment does not extract any of the nitrogen. Such bone, therefore, may contain a considerably higher percentage of nitrogen, and a correspondingly lower percentage of phosphoric acid, than raw bone. A good article may contain as much as 6 per cent. of nitrogen, with about 20 per cent. of phosphoric acid. The availability of such bone when finely ground should be a little greater than that of ground raw bone, but it would still be a rather slow acting fertilizer.

(*d*) *Bone ashes* — Bones were formerly collected in considerable quantities on the prairies in the western part of the United States and in South America in regions so distant from roads and railroads that their transportation would not pay on account of their bulk and weight. Such being the case, these bones were sometimes burned, and the ash, which, of course, would have much less bulk and weight, was sent to market. Burning the bones resulted in the loss of whatever nitrogen they contained, this being driven off into the air. Bone ash is very rich in phosphoric acid, which

exists in three-lime form. South American bone ash usually contains about 36 per cent. of phosphoric acid. Its mechanical condition is excellent. It is a slowly-acting fertilizer, but on account of its convenient and concentrated form is quite a desirable one. The supply, however, at present is very small. It is no longer important in our markets.

(*e*) *Boneblack or bone charcoal* — Boneblack is manufactured primarily for use in refining sugar, but after it has served this purpose it comes into the market for use as a fertilizer. In the manufacture of boneblack the nitrogen and the water contained in the original bone are driven off. As a consequence boneblack is much richer in phosphoric acid than the original bone. It usually contains about 32 per cent. of phosphoric acid. Boneblack, however, being only a special kind of charcoal, like all other kinds of charcoal, resists disintegration and decay in marked degree. Charcoal is one of the most imperishable of substances. For this reason the phosphoric acid of boneblack would become available only with extreme slowness. Boneblack, then, containing phosphoric acid in three-lime form, though a valuable material for the manufacture of a superphosphate, cannot with advantage be used in the undissolved form.

359. *Natural mineral phosphates.* (*a*) *Apatite* — Apatite is a crystalline mineral found in Canada and also in Norway in very large quantities. It is exceedingly hard and refractory. It is, however, very rich in three-lime phosphate. Canadian apatite usually contains about 38 per cent. of phosphoric acid, being, therefore, one of the richest of all the phosphate rocks. Apatite must be very finely ground if its phosphoric acid is to become to any extent available, and even when ground as fine as possible its action is exceedingly slow. In such experiments as have been tried in the United States, comparing this phosphate when fine-ground with other natural mineral phosphates, apatite has commonly given the poorest results. It may be doubted whether it can ever prove profitable to use this phosphate in that form. It is, however, valuable as a foundation for the manufacture of superphosphates.

(*b*) *South Carolina rock phosphate* — The rock phosphates of South Carolina are considered to be the fossil dung and animal remains, mostly

of fish-eating fowls. It is found both in river valleys and in the beds of rivers in some parts of South Carolina, in the form of irregularly shaped stones or rocks. The South Carolina rock must be ground very fine to become to any considerable extent available. In this form it is sometimes bought and sold under the name "floats." This phosphate usually contains about 26 per cent. phosphoric acid in three-lime form. In such experiments as have been tried in the United States comparing South Carolina rock with other natural mineral phosphates, it has been found the best. Even then it is a very slow-acting fertilizer, and it is perhaps doubtful whether its use in the form of floats can be generally recommended. On such soils as are fairly moist and rich in humus it seems probable that the phosphoric acid of the floats will become available with sufficient rapidity to make their employment, in part at least, in place of higher-priced superphosphates sometimes advisable. The chief use of the South Carolina phosphate, however up to the present time, is for the manufacture of superphosphates.

(*c*) *Florida phosphates* — There are three varieties of mineral phosphates found in Florida, known respectively as rock, pebble, and soft. The rock phosphate is of the highest grade, containing about 40 per cent. phosphoric acid in the three-lime form. The rock is less variable than the other Florida phosphates. The pebble phosphate may sometimes contain as much as 40 per cent. of phosphoric acid but it is somewhat variable. The soft phosphate is very variable, usually containing considerable clay, the phosphoric acid ranging from about 18 to 30 per cent. In the pebble and soft Florida phosphates the acid is in the three-lime form as in the rock. The soft Florida phosphates are easily prepared for use and are said to be much employed in the South. Owing to their low grade it would hardly pay to transport them to the North. The freight charge on one ton of low-grade material would be as heavy as on the same quantity of high-grade, but a ton of the low-grade soft phosphate might contain only about 360 pounds of phosphoric acid, while a ton of the high-grade rock phosphate would contain 800 pounds. The Florida rock phosphate has been under trial in the Massachusetts Experiment Station in comparison with

numerous other phosphates for a considerable number of years. The results of its use have been very poor. It seems to be more slowly available than the other natural mineral phosphates, apatite perhaps excepted. The use of Florida phosphates in the North, even in the most finely ground condition, is not likely to prove profitable, but these phosphates are valuable for superphosphate manufacture.

(*d*) *Tennessee phosphate* — The deposits of rock phosphate in Tennessee are of comparatively recent discovery (November, 1894), but since their discovery the mines have been rapidly developed and the quantity of phosphate rock now derived from these sources is large. In composition the Tennessee phosphates are somewhat variable. They usually contain from 30 to 32 per cent. of phosphoric acid in the three-lime form. Experiment has not yet determined the extent to which this phosphate in the fine-ground form may become available. It must, of course, be rather slow-acting. It is used almost exclusively for superphosphate manufacture.

(*e*) Various sections in the United States possess extensive deposits of rock phosphates, very large quantities of which have been discovered in the geological surveys of the last few years. Prominent among such deposits are those in Arkansas, Idaho, Wyoming, Utah, and Montana. All these phosphates furnish phosphoric acid in relatively highly unsoluble forms. They will, however, prove valuable as a basis for the manufacture of acid phosphate and probably for use in fine ground form under some conditions.

360. *Phosphatic guanos* — Deposits of guanos have been discovered on a number of islands in the West Indies, in the Gulf of Mexico, and the Caribbean Sea. These guanos are chiefly modified excrements of fish-eating fowls, but as the localities named all have abundant rains the nitrogen which was originally a part of the droppings of these sea fowls has been lost. The material remaining is, however, rich in phosphoric acid in the three-lime form.

Mona guano is one of the best known of these phosphates in the Northeastern states. It is in a good mechanical condition for application and in experiments comparing it with fine-ground South Carolina rock it has given rather quicker results. It must be considered, however, a rather slow-acting fertilizer. There are numerous other phosphates of the same character usually bearing the name of the locality from which they come; but in many cases the islands from which these phosphates come are small, the supply is soon exhausted, and a phosphate which is for a time of some importance disappears from our markets. On the whole, the phosphates of this class cannot be considered to have much importance for the Northeastern states.

361. *Basic or phosphatic slag* — This material, which is also sometimes known as Thomas slag and to which the name "odorless phosphate" has been applied by some dealers, is a by-product in the manufacture of steel of a certain quality. Practically all iron ores contain phosphorus. This phosphorus must be separated from the iron in order to produce a good grade of steel. This result is most perfectly and cheaply accomplished by mixing with the iron large quantities of lime. Under the intense heat to which the mixture of iron and lime is subjected in the process of manufacture the phosphorus is changed into phosphoric acid and unites with a part of the lime. The material as it leaves the furnace is in the form of a hard slag. This must be ground very fine in order to render the phosphoric acid to any considerable extent available. The finer it is ground the better. The composition of phosphatic slag is variable, the proportion of phosphoric acid ranging from about 15 to 20 per cent. It exists in the form of a double salt (phosphate and silicate) of lime; a slag is not a pure phosphate. It is mixed with large amounts of lime and oxid of iron. The phosphoric acid in the fine-ground slag is not soluble in pure water but a considerable proportion of it is soluble in weak soil acids or in the acid of the root of the growing plant. The phosphoric acid of fine-ground slag is much more available, therefore, than that in any of the natural rock phosphates. Many experiments to determine its value have been tried in Europe, where it is much more abundantly produced than here, and the results have been so good that it is now generally regarded as one of the best phosphates for general use. Basic slag is unfit for superphosphate manufacture because it contains large amounts of uncombined lime and iron oxid. The use of this phosphate is especially to be recommended on soils which are rich in humus and moist, because in these soils it becomes available most quickly. It may also prove exceptionally useful on soils which are sour, both because the phosphoric acid will become quickly available and because the lime in the slag will combine with the acid which makes the soil sour and thus increase its productiveness. Imported basic slag is now coming into general use in the Northeastern states. The iron ores of our Northern states are comparatively poor in phosphorus, and slag produced from them would be of a low grade, *i. e.*, containing only a small

percentage of phosphoric acid. The iron ores of the South are in general richer in phosphorus, and slag from that locality would be of better quality. The Nova Scotian slag is even richer than the European.

362. *Manufactured phosphates — superphosphates.*

(*a*) *What a superphosphate is and how it is made* — All the natural phosphates, such as bones in all their various forms and products, and all the mineral phosphates, may be used as bases for the manufacture of superphosphates. Whatever the material with which the manufacturer starts the method followed is essentially the same. It will be remembered that phosphoric acid in all the natural phosphates exists in combination in the three-lime form and that this is insoluble. It will be remembered, further, that one-lime phosphate is soluble, and the manufacture of superphosphate consists essentially in carrying out a method of treatment which has for its object changing the three-lime phosphate into the one-lime form. This is accomplished by mixing some strong acid with a natural material. This acid must be stronger than the phosphoric acid in order that it may be able to take away a portion of the lime from the three-lime phosphate when mixed with such a phosphate under the right conditions. It is essential that the quantity of strong acid added should be carefully regulated, for if too much is used it may make the material moist and unfit for convenient application. The only acid which at the present time is generally used in making superphosphates is the sulfuric. Two parts or equivalents of this added to the three-lime phosphate take away from that phosphate two parts of lime, leaving only one-lime in combination with the phosphoric acid, but in place of the two parts of lime taken away two parts of water enter the compound known as one-lime phosphate (357,*c*). That part of the lime which is taken away from the three-lime phosphate by the sulfuric acid combines with that acid to form a salt which is known as sulfate of lime. This is the same salt as that which is found in land plaster. Every superphosphate, then, contains a mixture of one-lime phosphate and plaster. Experience has shown manufacturers that it is best to use just a little less sulfuric acid than would be necessary to change all the three-lime phosphate into the one-lime form. This is because the material is more certain to remain in good mechanical condition for application. With too much

sulfuric acid employed in the manufacture a superphosphate becomes moist, since the sulfuric acid draws moisture from the air. It follows from what has just been stated, then, that every superphosphate contains a little three-lime or insoluble phosphate. Further, that proportion of the phosphoric acid which is combined in one-lime form is, so to speak, very poorly satisfied. The water which has taken the place of the lime does not make its loss good and so, since, as has just been stated, there is a little three-lime phosphate still remaining, this poorly satisfied phosphoric acid takes away some of the lime from this compound and as a result two-lime phosphate is formed. That part of the phosphoric acid which enters into this two-lime compound is known as reverted acid, as has been already stated (356,*d*). The reason why this name is given must now be evident. It is because the acid has gone part of the way back towards its original compound, as "to revert" means "to go back." Every superphosphate then contains :—

One-lime phosphate, which is soluble, and of course available.

Two-lime phosphate, not soluble in water, but available to plants, because soluble in weak acids.

Three-lime phosphate, which is insoluble, and but slowly made available.

Plaster, which, as will be pointed out later (387, *i*), is often a useful fertilizer.

In a well-made superphosphate nearly all the phosphoric acid exists in one-lime or soluble form. If there is much reverted acid, though this is available, the superphosphate is less valuable, because the reverted acid does not diffuse through the soil as quickly as does the soluble. If there is much insoluble or three-lime phosphate present, it is evidence that the maker, in order to save expense, has added too little sulfuric acid, and such a superphosphate is less valuable than one which has been more fully acted upon. Although, as has been stated, the treatment of any natural phosphate with sulfuric acid makes a superphosphate, by no means all fertilizers made in this way are so designated. Different names are applied to superphosphates made from different materials in order to indicate the source of the original material. Among such names dissolved bone, dissolved boneblack, and dissolved South Carolina rock are among those most

commonly met with. It should be remembered that if the original material contains nitrogen, the superphosphate also will contain it. The addition of sulfuric acid not only does not destroy or drive off the nitrogen, it renders it more available. Particular attention is called to the fact that, if equally soluble and available, phosphoric acid is equally valuable, no matter from what source it was originally derived, and one-lime phosphate, in superphosphate made from a mineral or rock phosphate, is just as acceptable to the plant as the one-lime phosphate in a superphosphate made from bones or boneblack. The same is true concerning the reverted acid from different sources, but the insoluble phosphoric acid in the superphosphate, *i. e.*, the portion which is still left in the three-lime form, will be more valuable in proportion as the original material was of a character to decay or disintegrate the more rapidly. This insoluble acid in a superphosphate made from bones is undoubtedly more quickly available than in a superphosphate made from rock.

(*b*) *Dissolved bone* — This name is used to designate a superphosphate made by treating ground bone with sulfuric acid. It contains nitrogen as well as soluble phosphoric acid, the usual percentage being about: nitrogen 2 per cent., phosphoric acid 13.

(*c*) *Dissolved boneblack* — This name designates a superphosphate made by treating spent boneblack with sulfuric acid. This superphosphate usually contains from about 15 to 16 per cent. phosphoric acid. It deservedly has a high reputation among farmers, but attention is here called to the fact that a given quantity of soluble phosphoric acid usually costs more in dissolved boneblack than in the superphosphate made from rock, while, as has just been pointed out (*a*), it is no more acceptable to the plant.

(*d*) *Plain superphosphate*, *acid phosphate*, *or dissolved rock* — All these names are used to designate one and the same thing, *i. e.*, a superphosphate made by treating a ground mineral or rock phosphate with sulfuric acid. The term acid phosphate is perhaps most generally employed. The acid phosphate in the markets of New England and New York is generally made from South Carolina rock, and when from this source contains about 13 per cent. of soluble phosphoric acid. Entirely similar superphosphates

may be made from either the Florida or Tennessee rock phosphates, or from the phosphatic guanos, but the percentage of soluble phosphoric acid in the superphosphates thus made will differ according to the richness of the materials used.

(*e*) *Double superphosphate* — A double superphosphate is made by dissolving the one-lime phosphate contained in an ordinary superphosphate in sulfuric acid, and then using this acid in which some phosphoric acid has already been dissolved for treating one of the natural phosphates. A superphosphate made in this way contains, besides the phosphoric acid in the natural phosphate last treated, that which was dissolved from the ordinary superphosphate first made. Such a superphosphate is, therefore, appropriately called a double superphosphate, because it may contain about double the quantity of soluble phosphoric acid contained in an ordinary superphosphate. Double superphosphates must prove of much value under circumstances where materials must be transported to considerable distances, owing to the fact that in a given weight they contain so much actual plant food. The use of such superphosphate reduces the cost of application, since there is less material to be handled. Double superphosphates, however, are not yet used to any great extent in this country.

LIV — THE SELECTION OF PHOSPHORIC ACID FERTILIZERS.

363. *Should a natural phosphate or superphosphates be chosen?* — One of the first questions which will present itself to the mind of a farmer about to select a fertilizer which will furnish phosphoric acid is whether it will be advisable to depend upon one of the natural phosphates, or whether one of the soluble and immediately available superphosphates should be chosen. This question may best be considered under several heads.

(*a*) *Cost* — At the prices for which the different fertilizers furnishing phosphoric acid can be bought, it will be found that a pound of phosphoric acid in any of the natural rock phosphates can be bought for about 2½ cents. In the form of ground bone the cost of phosphoric acid is about 4 cents. In the different superphosphates this quantity of phosphoric acid in soluble form costs from 5 to 6 cents,— the lower figure in the superphosphates made

from rock, the latter in dissolved boneblack. From this statement as to the relative cost of a pound of phosphoric acid in the different materials, it must be evident that if nature will render the phosphoric acid in the natural phosphates available within a reasonable length of time, there may be a considerable saving in using such phosphates rather than in paying the higher price for the phosphoric acid in superphosphates.

(*b*) The nature of the soil affects the rate of availability of all the natural phosphates in marked degree. Soils admitting free movement of air and water, and containing considerable humus, and those which hold moisture well are much more favorable for their prompt action than soils very light and dry and poor in humus.

FIG. 64. POTATOES.

Box 1, soluble phosphoric acid; box 2, insoluble phosphoric acid — Florida rock; box 3, insoluble phosphate of iron and alumina; box 4, no phosphate added. *By courtesy of Maine Experiment Station.*

(*c*) The kind of crop which is to be grown must be considered in deciding this question. Some of our crops are very dependent upon a liberal supply of soluble phosphoric acid, while others seem to be able to extract the needed acid from comparatively insoluble sources of supply. As a rule those crops which have an extensive root system and a long period of growth can best feed upon the three-lime phosphates. Fruit trees and shrubs and Indian corn are examples. On the other hand, all the crops which belong to the cabbage and turnip family appear to be very dependent upon a liberal supply of soluble phosphoric acid in the soil.

(*d*) If the soil be very poor in available phosphoric acid, then it must

always be unwise to depend wholly upon the natural phosphates whatever the crop. If the farmer is convinced that the use of natural phosphates is desirable in order to save expenditure, then in such cases it will be best at the start to use both superphosphates for the immediate use of the crop and a moderate amount of some natural phosphate which shall gradually be rendered available for the use of crops in later years.

FIG. 65. OATS.

Box 1, soluble phosphoric acid; box 2, insoluble phosphoric acid — Florida rock; box 3, insoluble phosphate of iron and alumina; box 4, no phosphate added. *By courtesy of Maine Experiment Station.*

(*e*) *Results of experiments* — The Experiment Station of the state of Massachusetts has been engaged for some time in an attempt to determine whether it is ever expedient to employ the natural phosphates in place of the superphosphates, and for the purpose of comparing a few of the different natural phosphates with each other. In one set of experiments carried out in that state an equal money's worth of a number of different phosphates was applied to each of several plots for a number of years. The plots were of one-seventh acre each and the following phosphates have

been compared: Dissolved boneblack, ground South Carolina rock, Florida phosphate, Mona guano, and phosphatic slag. Under these conditions the crops on the dissolved boneblack were at first much superior to those obtained by the use of the other phosphates, but within a few years the crops on the phosphatic slag and the ground South Carolina rock became practically equal to those on the dissolved boneblack. Since 1893 none of these plots have received any phosphate, the idea being to determine the length of time during which the different phosphates would prove useful. All the plots in the field throughout the entire length of time that the experiment has continued have been liberally supplied with fertilizers furnishing the other necessary elements of plant food. A number of different crops have been grown in rotation upon this field and in the following order: potatoes, wheat, serradilla, corn, barley, rye, soy beans, Swedish turnips, corn, oats, and cabbages. Representing the yield of the plot which stands highest at 100 per cent., the relative standing of the different phosphates for the entire period during which the experiment has continued is as follows: —

South Carolina rock phosphate,	100 per cent.
Phosphatic slag,	99 " "
Dissolved boneblack,	97.7 " "
Mona guano,	95.4 " "
Florida phosphate,	64.2 " "
The plot which received no phosphate,	55.4 " "

It will be noted that in these experiments both the South Carolina rock and the phosphatic slag have given larger yields than the dissolved boneblack. The Mona guano is not far behind, but the Florida phosphate has shown itself to be much inferior to the others. When it is further stated that calculation shows that those plots to which the natural phosphates were applied still contain a considerable amount of the phosphoric acid which they have received, while nearly all of the phosphoric acid applied in the dissolved boneblack has been removed in the crops, the conclusion seems inevitable that in this case the use of natural phosphates has paid; for it is reported that the crops have invariably been large on all the better plots in this experiment. In what has been said concerning bone

meal, it will be remembered that the results in the Massachusetts Experiment Station indicate this to be an efficient fertilizer; it would appear, therefore, that the use of natural phosphates may sometimes be advisable.

364. *Which natural phosphates should be used* — The results in the experiments which have just been described throw some light upon this question, although further investigation comparing bone meal with the other natural phosphates is desirable. The leading points which must be considered in deciding the question as to which natural phosphate should be selected are cost and probable availability. The rock phosphates furnish a pound of phosphoric acid cheapest but it can hardly be doubted that the phosphoric acid in them will become available more slowly than in bone. The finest ground bone seems likely to prove in many cases the most satisfactory natural phosphate, although on soils rich in humus the rock phosphates may prove satisfactory, while phosphatic slag, as it becomes more abundant and cheaper, will without doubt be satisfactory for many uses, for such experiments as have been tried comparing it with bone meal and other natural phosphates indicate that it is superior in availability to any of them. Many hold that it is fully one-half as available in the first year as the superphosphates.

365. *In what quantity should phosphates be used?* (*a*) — It will be remembered that whether phosphoric acid be applied in soluble or insoluble form it is not likely to leach out of the soil. This fact has an important bearing upon the question which we are discussing. Since the phosphoric acid is not to any considerable extent liable to loss by leaching, it is evident that it is unnecessary so carefully to avoid application of phosphates in quantities which will furnish more available food than the plant will immediately require, as is the case in dealing with fertilizers supplying nitrogen, which is subject to loss. True, in one sense, whatever is applied to soil in excess of such amount as is necessary to give a good crop is so much capital locked up and returning no interest. It is equally true, however, that our crops do not yield the largest possible product of which they are capable, unless the soil is liberally supplied with food in available form. No crop is able to find the last ounce or pound of plant food in the soil, and at

the same time give a profitable yield. We must, for best results, have a considerable accumulation of stored plant food in the soil. Since, then, phosphoric acid is not liable to loss, it is undoubtedly good practice to apply fertilizers supplying it rather freely until the soil becomes well stocked with this important constituent. A great German authority, Wagner, advises using phosphates freely until the soil is so rich in phosphoric acid that the crop for a year or two will be equally good whether or not the phosphate is applied when it is planted or during its growth. Whether the soil has reached this condition can be easily determined. Manure all parts of the field with fertilizers supplying nitrogen and potash liberally. To most of the field apply also a quick-acting phosphate, but leave several strips running entirely across the field without phosphate, watch the growth of the crop carefully throughout the season, determine the yield on the strips which were left without phosphate as compared with the average yield of the rest of the field, and it will be easy to decide whether the soil is in the condition into which Wagner advises bringing it. It will not be necessary in carrying out this plan to very carefully measure and stake plots of exact areas. The available phosphate can be applied broadcast after the crop is planted, the person applying being guided by the rows, here and there skipping strips including three or four rows of such crops as are commonly planted from about 3 to 3½ feet apart. If it be found, as a result of such an experiment, that the crop is just as good on these rows to which no phosphate was applied as on the others, then in future years it will be safe to apply yearly sufficient phosphate to furnish just as much phosphoric acid as the crop of the previous year removed from the field ; or perhaps for safety a quantity very slightly in excess of such amounts. A table showing the amounts of phosphoric acid, as well as the amounts of nitrogen and potash, removed in crops will be found on page 68.

(*b*) Particular attention is here called to the fact that the liberal use of superphosphates has been found to very greatly hasten the development of crops ; in other words, it makes a crop earlier, and tends to cause it to mature within a shorter time. In all cases, therefore, where early maturity is particularly desirable, superphosphates should be rather freely employed.

(*c*) In determining in just what amounts the various phosphate fertilizers should be used, it is necessary to take into account the phosphoric acid which may be furnished by manures, provided these as well as fertilizers are used. If, however, the fertilizers are used alone, then it is believed that the useful application per acre will, as a rule, be found to lie between the amounts given below: —

Bone meal,	600 to 1,200 lbs.
South Carolina rock phosphate,	400 to 600 "
Phosphatic slag,	800 to 1,200 "
Superphosphates,	300 to 600 "

LV — FERTILIZERS USED CHIEFLY AS SOURCES OF POTASH.

366. *Classes of potash fertilizers* — The number of fertilizers which are used chiefly as sources of potash is less than the number in the two classes which have been considered, and all the different materials may be included under two heads: —

1st. Wood and other ashes.

2d. German potash salts.

Attention is here called to the fact that a number of the vegetable organic fertilizers used chiefly as sources of nitrogen contain also small amounts of potash.

367. *Compounds of potash in different fertilizers* — In all kinds of ashes the potash exists chiefly in the form of carbonate, though to some extent as silicate. Carbonate of potash is a soluble salt; the silicate is not ordinarily directly soluble in pure water, but may be slowly dissolved in the acids of the soil and by plant roots. In some of the crude or natural German potash salts the potash exists in the form of sulfate, in others as chlorids. The natural salts are very largely used as the bases for the manufacture of more concentrated potash fertilizers. Among such fertilizers are some furnishing potash as sulfate, others in which it is present as chlorid, and still others (though these are less common) in which the potash is combined as carbonate or silicate. All these potash salts are soluble. It will be remembered, however, that the soil has the power to fix potash from its soluble

compounds (127). Being soluble when applied, potash salts diffuse throughout the soil within a comparatively short time.

368. *The important potash fertilizers named* — The potash fertilizers most often employed in the Northeastern states are: wood ashes; kainite; muriate of potash; sulfate of potash, high grade; and sulfate of potash, low grade (also called sulfate of potash-magnesia).

369. *Wood and other ashes.* (*a*) *Wood ashes, unleached* — The name wood ashes ought to be always understood to designate the pure and untreated product from the burning of wood, but as these ashes are frequently leached for the extraction of potash it may be necessary in some localities to specify "unleached" in order to secure ashes of good grade. Wood ashes contain practically all the mineral elements found in wood. They are rich in lime and contain magnesia, soda, and phosphoric acid in considerable quantities as well as potash. One example only will be given showing complete composition, viz.: Oak ashes, potash, 10 per cent.; soda, 3.6 per cent.; magnesia, 4.8 per cent.; lime, 73.5 per cent.; sulfuric acid, 1.4 per cent.; silica, 1.1 per cent.; and phosphoric acid, 5.5 per cent. The composition of wood ashes varies with the species of the tree from which the wood comes, with the soil in which the tree grew, and with the part of the tree burned. Thus, for example, pure ashes of the different species named contain potash as follows: Oak, 10 per cent.; beech, 16.1 per cent.; walnut, 15.3 per cent.; elm, 24 per cent. Ashes from twigs and small branches are richer than those of trunk wood, and in general the smaller and younger the wood burned the better are the ashes. The proportion of potash in wood ashes may vary from about 5 to 20 per cent. The presence of charcoal in ashes decreases their value. Ordinary house ashes which have been well kept usually weigh about 48 pounds to the bushel and contain about 4 pounds of potash in that quantity. Storer, in selected samples of house ashes, found potash, 8.5 per cent., or 4¼ pounds per bushel; phosphoric acid, 2 per cent., or 1 pound to the bushel. The presence of such amounts of potash and phosphoric acid would at present prices make such ashes worth about 20 cents per bushel for these elements of plant food alone, but, as has been stated, ashes contain a great deal of lime and considerable of

other constituents which may prove valuable. In the opinion of Storer the indirect fertilizer action of ashes due to the presence of these constituents is likely to be worth from 10 to 15 cents per bushel. On this basis a ton of such ashes would be worth, according to Storer, from about $12 to $14. House ashes cannot be purchased in most places in any considerable quantity. The only available source of supply of wood ashes in large amounts is Canada. Canada wood ashes are low-grade ashes, not infrequently damp and apparently either partially leached or mixed with some foreign matter. They will not as a rule be found to contain more than 5 per cent. of potash and 1.5 per cent. of phosphoric acid. Wood ashes are an excellent fertilizer for general use, especially on all soils which are rich in humus, which they will help to disintegrate, and for those which may be sour, which they will help to sweeten. The potash in ashes, however, costs more than in the German potash salts, and unless the indirect action of ashes is greatly needed it will be better economy for the farmer to procure potash in the form of one of the German salts. Wood ashes contain the different plant food constituents in such form that their action is rather slow; but both the potash and the phosphoric acid are available to crops with moderate rapidity and neither will be subject to loss.

(*b*) *Leached ashes* — Ashes are leached by treatment with hot water for the purpose of extracting as much potash as possible. Air-slaked lime is mixed with the ashes before treatment as it increases the solubility of the potash. When the process of leaching is thoroughly carried out about four-fifths of the potash is extracted. Leached ashes, therefore, will usually contain only about 1 to 2 per cent. of potash and must rank as a very low-grade potash fertilizer. They are included here simply because they belong to the same class with unleached wood ashes. Leached ashes should never be selected where much potash is needed. They are more valuable for indirect than for direct fertilizer action.

(*c*) *Lime-kiln and brick-kiln ashes* — These in most cases are impure wood ashes, diluted in the one case with more or less refuse lime and in the other case with brick dust, etc. Such ashes are very variable in composition but as a rule will contain considerably less potash than wood ashes.

In some cases coal is used as the fuel in whole or in part. Under such circumstances the ashes from either lime or brick kilns would have very little value. Even when of the best quality, where wood is the only fuel used, such ashes are valuable more for their indirect than for their direct action.

(*d*) *City ashes, garbage ashes, etc.* — Within recent years some of our cities burn a portion of their garbage in especially designed furnaces and they offer the ashes for sale under various names, most common among which are such as stand at the head of this paragraph. Such ashes, owing to the variation in the nature of the material burned, vary widely in quality. As a rule they are relatively richer in phosphoric acid than wood ashes. They can be safely purchased only with definite knowledge of their composition. They are likely to be rather slowly available.

370. *German potash salts.* (*a*) *Origin and nature of the natural deposits* — In several parts of Germany, notably in Stassfurt and vicinity, are found enormous natural deposits of salts of a number of different kinds lying at a very considerable distance below the surface. These salts are believed to have been left behind by the evaporation of enormous quantities of sea water in remote geologic times. The mines in Germany constitute at present much the most important sources of fertilizer potash in the world. They are worked and controlled by a syndicate. In these deposits are found many different mineral salts containing potash, several of which contain that element in such quantities as to make their use in ground form profitable in regions not too remote from the mines. There are but few of them which contain potash in sufficiently large proportions to make their transportation to a distance profitable, because, in these comparatively low-grade materials, with every pound of useful potash must also be transported a considerable number of pounds of other elements which are either valueless or comparatively valueless as fertilizers.

(*b*) *Kainite* — This is the only natural or crude potash salt which is imported into this country in any considerable amounts. This salt contains from 12 to 13 per cent. of potash in the form of sulfate. With this sulfate of potash there is found considerable sulfate and chlorid of magnesia

together with a large amount of common salt (chlorid of soda). The price per ton of the kainite is so much below that of the higher grade potash fertilizers that it is not infrequently used, the usual charge for it being from $12 to $15 a ton, while the high-grade sulfate and muriate of potash cost from $40 to $48 per ton. The cheapness of kainite, however, is only apparent. One ton of it contains only about 250 pounds of actual potash, and a single pound of potash, therefore, costs from about 5½ to 6 cents. The same amount of potash in the much higher priced sulfate and muriate can be bought for from 4 to 4½ cents. Unless, therefore, the salts of magnesia and the common salt found in kainite are needed, kainite is the more costly potash fertilizer. The salts of magnesia and common salt will doubtless occasionally prove useful because of their indirect manurial action. They will have a tendency to render soils somewhat more compact and to attract moisture. They may, therefore, prove highly useful on the lighter soils. The sulfate of magnesia, moreover, may have beneficial chemical effects upon the soil. It often helps to render constituents found in the soil more available. It will be seen, therefore, that the question whether kainite should be preferred to one of the higher grade potash salts is not an easy one to decide. Evidently if the object in view is simply the supply of potash, kainite should not be chosen, but if the indirect effects above spoken of are needed it may be wise to use it. It cannot be doubted, however, in view of the results of the experiments to which attention will be called when speaking of muriate of potash, that the heavy application of chlorids (chlorid of magnesia and chlorid of soda or common salt) incidental to the use of kainite in large quantities will often prove injurious, as it must increase the loss of lime in drainage waters.

(*c*) *Muriate of potash* — Muriate of potash is a commercial name used to indicate the salt formed by the union of potash and hydrochloric acid or chlorid of potash. It is the name by which this fertilizer is generally known among farmers. The muriate of potash found in our markets is very even in quality and contains at least 50 per cent. of actual potash. At present prices it is the cheapest source of fertilizer potash, one pound of which at $40 per ton for the muriate costs only 4 cents. Since muriate of

potash is the cheapest source of potash it is without doubt more frequently used than any other potash salt. Particular attention, however, is called to the fact that there are certain crops whose quality is injured by the chlorin which this salt contains. Among the more important of these crops are potatoes, sugar beets, and tobacco. There are a number of other crops for which this form of potash appears to be inferior to sulfate. Among these may be mentioned the onion. Attention is further called to the fact that muriate of potash should never be used in connection with sulfate of ammonia. If so used there is an interchange of acids and bases, resulting in the formation of chlorid of ammonia, which is poisonous in its effects upon vegetation. It is doubtless true that when muriate of potash can be applied some months previous to the planting of the crop the injurious constituent — chlorin — will be largely washed out of the soil before the crop is planted, so that the quality may not suffer injury. Very special attention, however, is called to the further fact that if chlorin is washed out of the soil it does not go alone. It combines with some base to form a soluble salt and one of the most common results is the formation of chlorid of lime, which washes into the subsoil or passes out of the soil altogether with drainage waters. The loss of lime which is thus caused may prove a serious matter in many soils. Experiments in the Massachusetts Experiment Station have shown beyond a doubt this increased loss of lime which results when muriate of potash is extensively used and the decline in pro-

Unlimed. Limed.

FIG. 66. ONIONS: Product of 1-20th acre on land manured for nine years with muriate of potash only.

ductiveness which follows such loss. Thus, for example, on one of the fields of the Massachusetts station on a plot which had been yearly manured with muriate of potash alone for ten years, the yield of corn in 1898 was only about 15 bushels to the acre. This plot received a heavy application of lime the following spring and was once more manured with muriate of potash in the same quantity as before. The yield was at the rate of about 50 bushels of shelled corn to the acre. Numerous experiments in Massachusetts and at other stations have shown that where muriate of potash is continuously used in liberal amounts the soil, unless at the start exceptionally rich in lime, becomes so far exhausted of this element as to require heavy liming. The application of lime of course increases the cost of raising a crop, and, though the lime may sometimes be required even where muriate of potash is not used, the fact that where it is used lime must be more frequently applied may well cause the farmer to hesitate to employ this salt continuously. True it contains the cheapest potash, but the apparent saving in potash may be more than offset by the increased cost of more frequent liming. One more point should be stated: The muriate of potash has a somewhat similar effect upon soils to that mentioned under kainite, *i. e.*, it tends to render the soil more compact and enables it to hold moisture more permanently. For these reasons the use of muriate of potash on the lighter soils is likely to be attended with better results than on the heavier. For the ordinary crops of the farm muriate of potash applied at the time of planting may safely be used. This salt is without doubt more largely employed by manufacturers in making mixed fertilizers than any other form of potash.

1. 2.

FIG. 67. CORN: 1, After eleven years' use of muriate of potash at rate of 160 pounds per acre, 49.75 bushels grain, and 2,760 pounds of stover. 2, With nothing, 3.88 bushels of grain and 730 pounds of stover.

(*d*) *High-grade sulfate of potash* — This salt is manufactured from low-grade salts in Germany, and as found in our markets is uniform in composition, containing about 51 per cent. of actual potash. One pound of potash in this salt costs at the present time (1901) about 4½ cents, a ton of this salt containing 1020 pounds and costing about $45. This is the most concentrated potash salt available for use and it is the belief of the author that everything considered it is the best potash fertilizer available at the present time. It may safely be used for all crops. It does not tend to increase the loss of lime from the soil to as great an extent as does the muriate and, therefore, although a pound of potash costs about one-fourth of a cent more in this salt than in the muriate, it seems probable that in most cases, since so frequent liming would not be required with this salt as with the muriate, the ultimate financial result will be better if this be selected. This salt does not attract moisture and does not tend to make soils more compact. It is, therefore, much better adapted to heavier soils than the muriate, and, since it remains permanently dry, it is better to use in mixture with other materials than the muriate, as the mixture is less likely to become lumpy.

(*e*) *Low-grade sulfate of potash* — This salt, which is also known by the name potash-magnesia sulfate, is manufactured in Germany from low-grade natural salts. A number of different low-grade potash salts are made in that country; but, as a rule, only one is imported into this country and that contains about 26 per cent. of actual potash. Practically speaking, it will answer if we consider that this salt contains one-half the percentage of potash found in the high-grade sulfate or the muriate. When the last named potash salts can be purchased at the prices which have been named the low-grade sulfate costs about $25, and as one ton of this salt contains about 520 pounds of actual potash, a single pound of potash costs about 5 cents. As a source of potash, therefore, this salt is somewhat dearer than the higher grade salts, but in some cases there is no doubt that the sulfate of magnesia it contains may prove useful. The Germans speak of this salt as a "chemical plow" because it helps to make plant food available by chemical means. This chemical action may prove of much importance on

some soils, and on some it may be that magnesia is needed as an element of plant food, but whether this constituent of the low-grade sulfate of potash would prove useful or not can only be determined by experiment. This salt of potash has the same physical characteristics as the high grade and may be safely used on all sorts of soils for all crops.

(*f*) *Carbonate of potash-magnesia* — In recent years the German manufacturers have turned out a small quantity of carbonate of potash-magnesia, having believed that it would prove especially useful in tobacco growing. This fertilizer contains between 18 and 19 per cent. of potash. It is not yet imported into this country in any quantity as its price is such that the potash in it costs considerably more than in the other salts which have been spoken of. Numerous experiments have been carried out in the Connecticut Experiment Station for the purpose of comparing this salt with other fertilizers furnishing potash for tobacco, and it is reported that the quality of the leaf produced where carbonate of potash-magnesia was used was the best among all the samples raised. The carbonate of potash-magnesia is in very fine mechanical condition and remains dry. It is to be hoped that it may later be offered at a price which will bring it within the reach of farmers. At the present time (1901) it cannot be considered important.

(*g*) *Silicate of potash* — This is the latest product of the German works, and, like the carbonate of potash-magnesia, it was brought out in the hope that it would prove a valuable fertilizer for tobacco, the quality of which when raised on sulfate of potash although fairly good is not altogether satisfactory. The reports on European experiments in the use of this potash salt for tobacco are very favorable. It has been tried in this country in the Connecticut Experiment Station and it produced a leaf of fine appearance. The salt contains about 21 per cent. of potash but it has the undesirable quality of absorbing a large amount of moisture from the air. So great is its tendency to take up moisture that it can be kept from caking only by mixing with some dry powder. For this purpose the Germans use powdered peat. This salt dissolves somewhat more slowly than the other potash salts, but most of it dissolves within a short time in boiling water and there can

be but little doubt that it will become available in the soil with sufficient rapidity to meet the requirements of most crops. Experiments in the Massachusetts Experiment Station have shown this to be the case, for the crops raised on soil which was naturally quite poor in potash have been equally as good on this as on the other potash salts. This fertilizer at present (1901) is too high in price to make its use for the general crops of the farm advisable.

371. *Relative availability and value of potash fertilizers* — The potash in all potash fertilizers which have been considered is either soluble or mostly soluble. It therefore moves readily throughout the soil. As a rule the potash after application enters into some new chemical compound which is less soluble and in the new form is chemically held by the soil (127).

Fig. 68. Sixth year of manuring as indicated by plot label.

The compound formed in the soil is usually silicate, and in this form the potash, though gradually available to plants, is not likely to wash out of the soil. Numerous experiments to determine the relative value of some of the different potash fertilizers for crops have been carried out in Massachusetts. On one field the high-grade sulfate of potash has been compared with the muriate of potash for various crops, the experiment continuing for nine years. In this set of experiments bone meal at the rate of 600 pounds per

acre has been used with each of the potash salts throughout the entire period covered by the experiment. The following crops have, with very few exceptions, done much the best on the sulfate of potash: potatoes, clovers, cabbages, and soy beans. Corn, grasses, oats, barley, vetches, and sugar beets have given equally good yields on the muriate of potash. The quality of the crops of potatoes and sugar beets has been best on the sulfate. Potatoes are more mealy, containing as a rule from 3 to 4 per cent. more starch. Sugar beets are sweeter, containing about 2 per cent. more sugar. Taking into consideration all the crops which have been raised during the

FIG. 69. Sixth year of manuring as indicated by plot label.

continuance of this experiment, it is found that if the yields produced on the sulfate of potash be represented by 100 those on the muriate are represented by 98.1. Taking into account only those crops which show a preference for sulfate of potash, and representing the yield upon that salt by the number 100 the yield on the muriate is 88.6. The Massachusetts Experiment Station reports fourteen different experiments comparing high-grade sulfate with muriate of potash for potatoes. If the yield on the sulfate of potash in all these experiments be represented by 100 that on the muriate is represented by the number 94.1. It has been noticed that with most

crops the yield gradually decreases if muriate of potash be continually used, though at first it may produce crops equal to those produced by the sulfate. The loss of lime which the muriate causes undoubtedly accounts for this result. The Massachusetts Experiment Station gives the results of numerous experiments comparing high-grade sulfate with muriate of potash for garden crops, and has called attention to the fact that as a rule the sulfate is much superior to the muriate for such crops as make their growth chiefly in the early part of the season. Representing the yield of such crops produced by sulfate of potash by 100, that on the muriate is represented by 91.3. Representing the yield of late garden crops produced by the sulfate of potash by 100, that produced by the muriate is represented by the number 91.5. Where these two potash salts have been used in connection with stable manure the difference is still greater. For the early crops the yield on the sulfate of potash being taken as 100, that on the muriate is 86.1. For the late crops the yield on the sulfate is 100, that on the muriate is 98.8. These results are not based on the experiments of a single year but on experiments continued for a number of years upon the same plot. The Experiment Station in Massachusetts has also begun experiments to determine the relative value of some of the other potash salts, and the results of two or three years show that the low-grade sulfate and carbonate are nearly as good as the high-grade sulfate. A pound of potash in them, however, costs more than in the high-grade sulfate.

372. *Selection of potash fertilizers* — The figures which are given in the preceding paragraph indicate that as between the different potash salts the high-grade sulfate may generally be counted upon to give the best results. As between it and ashes we have no basis for comparison, but it is well known that the high-grade sulfate is a cheaper source of potash than ashes. It might appear, therefore, that this salt should invariably be selected as the source of potash, but there are certain conditions which should be given due weight. For the lighter soils and for the crops which make their growth chiefly in the latter part of the season the muriate may be equally as good and possibly better than the sulfate for occasional use. For continued use the sulfate should be selected. Attention, in conclusion,

is called to the further fact that the injurious effect upon the quality which has been noted in the case of sugar beets, potatoes, and some other crops can be avoided if the muriate be applied the previous fall. It is the chlorin in the muriate which proves harmful when this salt is applied in the spring. If it can be applied in the fall the chlorin will have been largely washed out of the soil before the next season of growth.

373. *Quantity of potash needed, and time for applying it* — In the general farm practice of the Northeastern states more potash than phosphoric acid is sold in the money crops of most farmers. Hay, potatoes, tobacco, onions, garden crops in general, and fruits are rich in potash and contain relatively little phosphoric acid. For every pound of phosphoric acid in such crops the farmer sells some two or three pounds of potash. Milk is the one product generally sold which contains more phosphoric acid than potash. On all milk farms, however, it is the general practice to buy and feed grains, mill feeds, etc., and all these are rich in phosphoric acid, so that the farm manures are enriched in this element. Further, it will be remembered that the potash in animal excrements is soluble and very subject to waste, while the phosphoric acid is insoluble and not equally subject to waste (291). In view of these facts it seems evident that potash should generally be relatively more abundant in fertilizers used on the farm than phosphoric acid. For many years farmers have been using phosphates or fertilizers rich in phosphoric acid. It is believed that this practice is a mistake and that potash should be more prominent among the fertilizers used on most farms. The quantity of potash which should be used naturally varies with circumstances. The lighter soils usually stand in greater need of it than those which contain more clay. Crops, too, vary widely in the degree of dependence they show upon a liberal supply of available potash. Among those known to be especially dependent upon liberal potash manuring may be named corn, potatoes, onions, roots, tobacco, and all legumes (clovers, peas, beans). The great German authority, Wagner, whose opinion concerning phosphoric acid has been stated (365, *a*), advocates a similar course in reference to potash fertilizers. Potash fertilizers, like those containing phosphoric acid, are not subject to waste. The plant does its

best only when there is a large supply of available food in the soil. Therefore, in Wagner's opinion, with potash as with phosphoric acid it is desirable to use fertilizers containing it for a time very freely. Such free use of potash fertilizers should be continued until the soil is so stored with potash that if its application be omitted for a year or two the crop is equally as good as with it. When this condition is reached it shows that the soil contains this element in available form in sufficiently large amounts for practical purposes. After the soil is brought into this condition it is sufficient to apply yearly or during any given rotation the same amount of potash as is removed in the crops. In many cases it will be found more convenient to apply the potash needed entirely to the crops in a rotation which are known to be most dependent upon potash manuring, rather than to apply annually. This practice will save labor. If manure is used for any of the crops in rotation, the potash which it contains must be taken into account. The method of experiment to determine whether the soil is sufficiently stored with potash is the same as that described under phosphoric acid (365, *a*).

374. *Wagner's rule for phosphoric acid and potash manuring illustrated* — In order to make perfectly clear the method of using fertilizers supplying phosphoric acid and potash recommended by Wagner, we will attempt to show its application under such circumstances as may be found on many New England farms. For the application of this rule the farmer must have ready access to sources of information as to the quantity of phosphoric acid and potash which would be taken from the soil by his leading crops. These quantities have been carefully computed and are shown in the following table : —

Crop.	Supposed Yield Per Acre.	Harvested Product Contains:— Phosphoric Acid. Pounds.	Potash. Pounds.
Corn	75 bushels grain, 2½ tons stover	42.0	74.3
Potatoes	300 bushels tubers	14.0	90.0
Mangolds	30 tons roots	56.0	228.0
Swedes	20 tons roots	59.0	196.0
Onions	800 bushels	54.0	104.0
Cabbages	20 tons	84.0	156.0
English hay	4 tons	31.0	122.0
Timothy hay	4 tons	37.0	116.8
Clover hay	4 tons	36.0	168.0

Knowing the product in any one year, as the intelligent farmer always does with substantial accuracy, he can by the use of this table readily determine the quantity of phosphoric acid and potash which the harvested crop has taken out of each acre cultivated. Let us suppose that the farmer's rotation is potatoes, corn, and two years of grass and clover. Let us suppose that his crops average: potatoes 250 bushels, corn 60 bushels and two tons stover, hay each year 2½ tons. These four crops will remove from the soil about 84 pounds of phosphoric acid and 289 pounds of potash. Let us suppose that the farmer makes some manure and that he applies the manure made to the corn crop at the rate of 12 tons to the acre. This amount of manure will supply 80 pounds of phosphoric acid and 120 pounds of potash (301). The total amount of phosphoric acid removed from the soil by all the crops of the rotation is only 84 pounds. It will be seen, therefore, that the manure alone furnishes nearly all the phosphoric acid which can be needed by the four crops. There is, however, a small deficiency and this together with a small margin to provide for any possible loss should be supplied to one of the crops in the rotation. If the potatoes are grown as an early market crop, there can be little doubt that the needed phosphate can be used to the best advantage for them, since the use of a soluble phosphate makes the crop earlier. One hundred pounds of acid phosphate ought to prove an ample quantity, as it will furnish 13 or 14 pounds of phosphoric acid. On considering the potash we find that the four crops remove from the soil more than double the quantity applied in the manure. There is a deficiency of no less than 169 pounds of this element. This should be largely applied to the potato crop, which, as has been pointed out, is very dependent upon a liberal supply of available potash, and it is suggested that the application of 250 pounds of high-grade sulfate of potash would probably prove beneficial. This quantity of sulfate of potash furnishes a little more than 125 pounds of potash, so that there is still a deficiency of 44 pounds. This would best be applied for the corn crop, which also is very dependent upon liberal potash manuring. It is believed that 100 to 125 pounds of muriate or high-grade sulfate of potash can be used to advantage with the manure for this crop. Under such a

system of manuring as has been outlined it is believed that the supply of phosphoric acid and potash in the soil would be permanently maintained, but it must be remembered that such manuring as has been suggested must be inadequate unless the soil has first been brought into such condition that the crops for a year or two are equally good whether phosphoric acid and potash are supplied or not. If the soil is not in such condition, then manures or fertilizers must be more freely employed until such time as this condition is reached. It is, in conclusion, evident that if the crops be greater than those which have been assumed, more liberal manuring will be called for.

It will be noticed that the quantity of nitrogen which may be required in such a rotation which would be furnished by the manure has not been taken into account. Nitrogen manuring must be placed upon a different basis from manuring with phosphoric acid and potash fertilizers, since it is subject to waste. It has been here purposely omitted, not because it is unnecessary, but because it can be better considered in a later paragraph (407).

LVI — COMPLETE FERTILIZERS.

375. *What a complete fertilizer is* — A fertilizer which furnishes the elements nitrogen, phosphoric acid, and potash in proportions supposed to be suited to the requirements of farm practice is called a complete fertilizer. None of the fertilizers which we have thus far considered are of this class, although some of them, as has been pointed out, contain all of the elements named. They are not complete, however, because in every case one of the elements has been present only in very small amounts. Practically none of the natural materials available for use as fertilizers are complete in the sense in which the word is here used. Complete fertilizers are produced by the mixture of a number of different materials. We may with advantage divide complete fertilizers into two classes, general and special.

376. *Complete fertilizers for general use* — The fertilizers of this class are rather indiscriminately recommended for use on crops in general and on all soils. From the very nature of the case it must be at once seen that it is an impossibility to produce a universal fertilizer. It is well known that

soils differ in their natural or acquired characteristics and that crops vary in their requirements. True, a fertilizer might be made containing an abundance of nitrogen, phosphoric acid, and potash, and if such a fertilizer should be liberally used, good crops of all kinds can undoubtedly be secured on all soils. Such a result is possible only because in the case supposed all the elements needed are supplied in large amounts, some almost certainly in excess of any possibility of usefulness. Economy requires that fertilizers should be adapted to the soil and the crop and that we apply only what is needed. Farming is not sufficiently profitable to make it expedient to go on applying elements of plant food in excess of what is useful. In view of these considerations it is evident that the general fertilizers can suit only those who are brain-lazy — those who do not care to study and think. No thinking farmer can be satisfied to blindly and thoughtlessly continue the "hit or miss" system of using general fertilizers. Further, a study of the results of analyses of so-called general fertilizers reveals the fact that many of them are not compounded to meet the requirements of general farming as well as might easily be the case. As a rule such fertilizers contain too large a proportion of phosphoric acid and too small a proportion of potash. The number of such fertilizers is enormous. The different brands commonly bear the names of the manufacturers. Their composition is guaranteed as is required by law and they usually contain what is claimed. They show no general agreement in composition and a particular description of different brands could have no permanent value.

377. *Special fertilizers* — A special fertilizer is one which is supposed to be adapted to the particular needs of a special crop or some few closely related crops. Each special fertilizer commonly bears the name of the crop or sometimes the names of a few crops for which it is made. Practically all special fertilizers contain each of the three elements nitrogen, phosphoric acid, and potash. There is great variety among such fertilizers. Special fertilizers are made for all our prominent crops and for each of these crops by many different makers. Thus, we have a very large number of corn fertilizers, still more potato fertilizers; we have tobacco fertilizers, onion fertilizers, grass fertilizers, grain fertilizers, fruit fertilizers, etc., etc.

Since it is claimed for each of these fertilizers that it is especially adapted for the crop whose name it bears, we are certainly entitled to expect that if these fertilizers are made with any definite knowledge as to the real requirements of a crop all those offered for sale in any given locality for a certain crop will have the same or at least a similar composition. Investigation reveals the fact that this is not the case. Different corn fertilizers offered by manufacturers or agents in the same town differ widely. We find as much difference between different kinds of corn fertilizers as usually exists between corn fertilizers as a class and fertilizers for other crops as a class. Evidently the makers do not agree as regards the requirements of corn. What has been said of the corn fertilizers is equally true of potato fertilizers, and, indeed, of practically all the special fertilizers that are made by any considerable number of manufacturers. Yet these different makers are all claiming to have a specific for each of the different crops. The simple fact that these specifics vary so widely leads to the inevitable inference that there is either a great lack of definite knowledge as to the requirements of the different crops, or else that commercial rather than scientific considerations determine the composition of the different fertilizers.

378. *Reasons why the system of using special fertilizers now practiced is criticised.*

(*a*) The system on which the special fertilizers are made and offered is wrong, for the reason that it disregards the well-known fact that soils vary in their manurial requirements. Such variation may be due either to the difference in the natural character of the soil connected with the kind of rock from which its constituents were derived or the manner of its formation, or it may be due to a difference in the kinds and amounts of manures which have been used and the crops which have been raised.

(*b*) The use of these special fertilizers hinders progress. The system is in some respects similar to that of quack medicines. The farmer calls for a specific just as the ignorant or unwise patient calls for a quack medicine, and just as the intelligent physician who studies the individual peculiarities and condition of the patient can select and use medicine with better results than can be obtained with any so-called specific, so the intelli-

gent farmer who will study the peculiarities and the condition of his soils and the special needs of his crops can do better than the one who blindly uses some special fertilizer which is recommended to him.

(*c*) As a rule fertilizers should be used to supplement and not to replace manures, and the selection of materials should vary with the kind and the quantity of manures applied. This factor the manufacturer of special fertilizers is of course unable to take into consideration. The individual farmer must do this for himself.

(*d*) Special fertilizers being employed, all the different elements of plant food, those furnishing nitrogen as well as those furnishing phosphoric acid and potash, are necessarily applied at the same time. This is often unwise, for many of the nitrogen-containing manures are liable to waste. Better economical results are frequently obtained by applying this separately in fractional applications at different periods in the growth of the crop.

(*e*) It is difficult for the Government and experiment stations so to control the manufacture and sale of these special mixtures as to prevent deceit and fraud. It is not the intention to imply that these are the rule. It is believed that most makers are honest, but it is especially pointed out that the analyses at experiment stations do not, and under present methods cannot, show the source from which the nitrogen contained in mixed fertilizers comes. The analysis shows the percentage, but, as has been pointed out (353), the value of equal quantities of nitrogen varies widely in the different materials. Whether the nitrogen in a special fertilizer is present in the form of nitrates, ammonia, or leather makes much difference in the value of the fertilizer, but the analyses at experiment stations do not as a rule show whether the one or the other of these substances, or others which might be mentioned, are employed. On the other hand, when the farmer buys such fertilizers as have been considered under the three leading classes he knows the source of the plant food and can estimate its probable value.

(*f*) When different materials are put together to make mixed fertilizers which must often stand some time before they are used, very undesir-

able changes, both chemical and physical, may take place. As a result of the chemical changes ammonia is sometimes lost through escaping into the air, as it does from a heap of decomposing manure. The intelligent manufacturer tries to avoid such mixtures as will be likely to cause such loss, but this it may be feared is not always accomplished. If both nitrate of soda and acid phosphate are included in the same mixture (and it is believed that they are often so included) there may be a considerable loss of nitric acid, for the phosphoric acid in the form in which most of it exists in acid phosphate, viz., one-lime phosphate, is but poorly satisfied (362,*a*) and it steals a part of the soda away from the nitric acid, leaving the latter uncombined and thus liable to escape. It is more likely to remain in the mixture, in which case it causes the rotting of the bag in which the fertilizer has been placed. Further, as a result of the change just described, and of other changes which may go on in the mixed fertilizers, the phosphoric acid is likely to enter into less soluble forms and so to become, though still available, less readily diffusible and therefore less valuable. It therefore happens not infrequently that as the result of combination of the different materials put into a mixed fertilizer it gets into a very hard and lumpy condition making its application difficult.

(*g*) Special fertilizers as now offered in the market are as a rule not correctly proportioned to give the best results of which the system is capable. They contain too high a proportion of phosphoric acid and too little potash in most cases.

(*h*) The plant food in a special fertilizer costs much more than in unmixed goods. The amount of plant food found in one ton of a special fertilizer can usually be purchased at from $6 to $10 less in unmixed materials and the mixing will not generally cost more than from $1.50 to $2. Voorhees reports as a result of careful investigation that the charges of the manufacturers and dealers for mixing, bagging, shipping, and other expenses are on the average $8.50 per ton. It is believed that it is well worth the while of farmers to save, as they easily may, a large part of this sum, for there is much farmers' evidence to show that the cost of home mixing need not exceed $2 per ton.

(*i*) It is claimed for the system of using mixed fertilizers that being composed of materials wisely selected, especially adaped to the crop, and of such a kind as to make the application of all the elements of plant food at one time without loss a possibility, there is much saving in trouble and in cost. To make two or more applications must of course require more time than to make a single application but it is believed that any saving due to this method is more than offset by the higher cost of the special mixed fertilizers.

1. 2.

FIG. 70. CORN, after 11 years' manuring as below shown.

1, Per acre, barnyard manure, 5 cords; cost, $25; grain, 75.9 bushels; stover, 5,350 pounds. 2, Per acre, 160 pounds of nitrate, 320 pounds of boneblack, 160 pounds of potash; cost, $12; grain, 72.3 bushels; stover, 4,450 pounds. Both limed the preceding year, 1 ton per acre.

(*j*) It is mentioned as a fact that should have weight with our farmers that in the country where all would probably admit the nature of fertilizers and the method of using them is best understood,— Germany, the system of applying mixed special fertilizers has been almost entirely given up. In that country the farmers are accustomed to make their own selections of materials, such as have been described in the first three classes, and to use them in accordance with the special requirements of different soils, different systems of manuring, and different crops.

LVII — INDIRECT FERTILIZERS.

379. *What an indirect fertilizer is* — A fertilizer which does not furnish either nitrogen, phosphoric acid, or potash, but which, nevertheless, increases productiveness because of some chemical or physical effect upon the soil, or upon some of the constituents of the soil, is an indirect fertilizer. In this connection attention is once more called to the fact that many of

the direct manures and fertilizers also exert indirect beneficial influences. These in all important cases have been pointed out.

380. *Indirect fertilizers named* — The more important indirect fertilizers are lime in its various forms, marl, land plaster, common salt, and sulfate of magnesia. Some authors include also sulfate of iron or green vitriol, coal ashes, and numerous other materials, but these are of very little importance.

381. *Lime* — It should be remembered that lime is an essential element of plants (26). It may therefore be needed for direct manurial action, but as a rule this is not the case, because the element is so abundant in most soils. The application of lime in any of its various forms is commonly beneficial rather because of some special effect or effects upon the soil than for the reason that it supplies a deficient element which the plant must take up as a food. In various parts of the United States are found soils which, although tilled with the utmost care and supplied with liberal amounts of the ordinary manures and fertilizers, are yet very unproductive. Sometimes crops are almost absolute failures though manures and fertilizers are used in very large amounts. This may be the case even when the field is not apparently in special need of drainage, although in very many instances it will be found that insufficient drainage has been an important factor in producing the existent conditions which are unfavorable to fertility. Wheeler believes that such soils are very common in Rhode Island and in southern Massachusetts, and experiment both in Rhode Island and Massachusetts has shown that the application of lime in some form to these unproductive soils has often proved highly beneficial. How best to determine whether soils will probably be benefited by liming is a most important question, but before considering it, it seems best to point out, first the effect of lime on plants, and second the effects of lime upon the soil.

382. *The effect of lime on the plant* — (*a*) Lime is absolutely necessary as shown by the fact that, if it be not supplied, the growth of the plant ceases as soon as it has made use of the small amount of lime contained in the seed.

(*b*) The amount of lime in plants depends in a measure upon the

quantity in the soil. No plant can develop without a certain minimum quantity, but if lime be abundant in the soil the plant takes more than this minimum, and within certain limits the more abundant lime is in a soil the larger is the percentage of lime in the plant. Fodder grown upon a soil rich in lime contains a larger quantity of that element than fodder of the same kind grown upon a soil poorer in lime, and the fodder richer in lime is better food, especially for growing animals, than is that which contains less lime. Limestone regions are generally noted for fine stock.

(*c*) The form of the plant differs with the amount of lime in the soil. The experienced eye recognizes at once whether the soil is rich or poor in lime by the growth of the crop. On soil rich in lime the plant is compact, short-jointed, stouter in the stem, and in the general development far more luxuriant than in soils poor in lime. In the soil rich in lime, moreover, the plants incline to far greater fruitfulness. Plants on soil poor in lime are long-jointed, slender, and comparatively feeble. They may blossom abundantly but produce little seed. Grains and grasses on soils poor in lime, because of their more slender form, are far more likely to lodge than on soils rich in lime.

(*d*) Different plants require differing amounts of lime in the soil. The various species of plants differ extremely in respect to the amount of lime required in the soil for good growth. Most of the plants belonging to the clover family require large amounts of lime in the soil. Lupine is an exception. Peas, beans, vetches, clovers of all kinds, and alfalfa require abundant lime. The cereal grains, and in short all grasses, require less lime. Most of the latter will do better with abundant lime but they can nevertheless perfect themselves if comparatively little be present in the soil. If a soil on which a variety of plants is growing, and more especially mowing, be limed, the effect upon the relative number of the different species is very marked. Thus, if a portion of a field in which the soil is not naturally rich in lime receive an application of this material while another portion is left without lime and then a mixture of grass and clover seeds be sown, it will appear after the seeds are well started as though clover had been sown on the limed part of the field and grass on the unlimed part.

This difference will be more marked if some nitrate of soda be applied. This will help the grass greatly but will not particularly benefit the clover. The kind of seed sown in mowings is not the only factor which influences the character of the growth. The chemical condition of the soil determines in a large measure which species will thrive. Clover and timothy will start well if the soil is well stocked with lime, while redtop may predominate if this is not the case. Wheeler of the Rhode Island Experiment Station has made extensive experiments to determine the relative need of lime by different crops. He has published lists of crops respectively benefited and injured by liming. From these lists I select a few of the more important: —

Usually Benefited by Liming.	Usually Benefited by Liming.	Usually Injured by Liming.
Lettuce,	Soy beans,	Lupines,
Spinach,	Carrots,	Millet,
Beets of all kinds,	Onions,	Redtop,
Cabbages,	Celery,	Blackberries.
Rutabagas,	Tobacco,	
Cauliflowers,	Strawberries,	
Barley,	Grass,	
Buckwheat,	Timothy,	
Oats.	Clover.	

Wheeler, and other investigators as well, have called attention to the fact that if potatoes follow too closely after an application of lime they are likely to be scabby. It has usually been found that corn is less benefited by liming than the other grains.

383. *The effect of lime upon the soil* — As has been stated, the beneficial effects of lime are usually due to some special action on the soil. The effects which may follow a heavy application of lime are numerous. They are best considered under two heads: Chemical changes, and mechanical changes. Under the first head are included changes which render plant food more available; under the second, changes which bring the soil into more favorable relations with water, air, etc.

384. *Chemical effects* — (*a*) Lime renders the potash of the soil more available. It has been pointed out that a large part of the potash of our

soils is present in comparatively insoluble silicates. Lime may decompose soil silicates, setting the potash in them free and thus greatly increasing its availability. Experiments have proved that when lime is applied to a soil originally poor in this constituent the plant is not only richer in lime but also in potash. The use of lime may, then, for a time have a similar effect to that of potash-containing manures, but it must be remembered that the lime does not supply potash,—it simply renders the potash in the soil more available and if the store of potash naturally present in the soil is small it will need liberal potash manuring all the sooner because of liming.

Air-Slaked Lime. Unlimed.

FIG. 71. POTATOES. Effect of lime in causing scab.
By courtesy of Rhode Island Experiment Station.

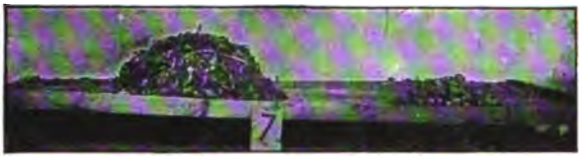
(*b*) The presence of sufficient lime in the soil prevents the soluble phosphoric acid applied in fertilizers from satisfying its hunger for a base by combining with iron or alumina, which is undesirable because phosphates of iron and alumina are very insoluble. When lime is present the phosphoric acid will take this by preference and the reverted phosphate thus formed is much more valuable than would be the phosphates above mentioned.

(*c*) Lime promotes the decomposition of organic substances — humus, sod, stubble, etc. — and thus hastens the time when the valuable constituents of these materials are ready for the use of the next crop. This effect

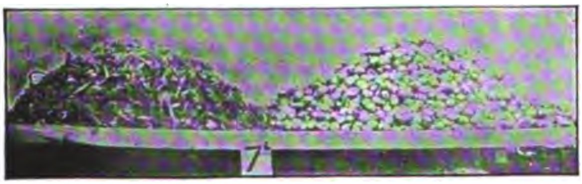
of lime is particularly valuable on the heavy, moist soils in which organic matter naturally decays slowly.

(*d*) Lime favors the change of ammonia into nitric acid, *i. e.*, it makes ammonia nitrogen more quickly available. The favorable effect of lime in increasing the yield where sulphate of ammonia is used as a fertilizer has been pointed out (350).

(*e*) Soils needing lime often contain free acid, *i. e.*, acid not combined with a base. Such soils are sour. Lime is the most effective agent which can be used to sweeten such soils. It is the heavier or poorly drained soils, those rich in humus, those imperfectly worked and aerated, and those on which such fertilizers as kainite and muriate of potash have been largely and continuously used, which are most likely to become sour. The favorable effects of employing lime when muriate of potash is extensively used has been pointed out (370, *c*).



Unlimed, yield at rate per acre, 9.23 bushels.



Limed, yield at rate per acre, 310.77 bushels.

FIG. 72. ONIONS: Product of 1-40th acre, tenth year; application yearly (nitrate of soda and muriate of potash).

(*f*) Soils sometimes contain injurious compounds of iron. These may be rendered harmless by the free use of lime.

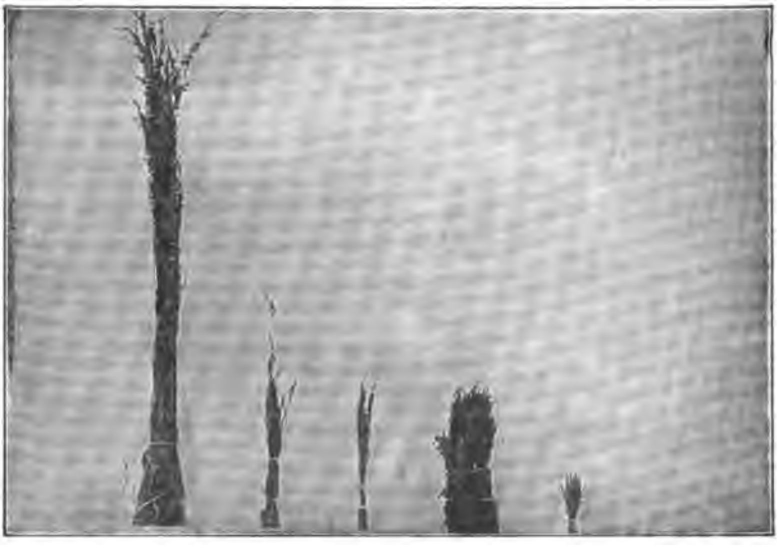
385. *Mechanical effects of lime* — Lime makes soil more mellow. On working, on the one hand, a soil poor in lime, or, on the other hand, one rich in lime, it will be noticed that the two soils behave very differently. The loam which contains little lime is made fine only with great difficulty. It adheres to all the implements used in it. A loam rich in lime crumbles far more easily. It is readily brought into good tilth, it does not adhere to such an extent to the implements used in it. If loam containing much lime

is exposed to the action of frosts the influence is highly beneficial. It becomes more mellow. Loam poor in lime, on the other hand, is not benefited to nearly the same extent. Loam of this kind turns up in tenacious clods. On lying undisturbed in spring or summer it forms a hard crust. Soil rich in lime crumbles on being turned over by the plow. If rich in clay and moist, it may be somewhat lumpy when turned but these lumps are not tough, they are readily broken. An open, porous soil allows water to penetrate quickly. Surplus water passes into the subsoil. Soil poor in lime and rich in clay is very impervious to water and after a heavy rainfall remains wet too long. The air cannot penetrate a soil of this character, and the absence of sufficient air as well as the stagnant water is injurious. As the result of an experiment it is reported that a layer of water about two inches thick required 26 days and 19 hours to pass through a clayey soil. After the soil was mixed with 2.5 per cent. of lime the same quantity of water passed through it in 7 hours. The explanation of this remarkable effect of mixing lime with clayey soils is that it causes the exceedingly fine particles of clay to gather in little balls. Between these little balls of clay, air and water circulate as between grains of sand, and it is to this particular effect chiefly that the great improvement in the heavy soils resulting from liming is due. The fact that certain fertilizers, among which kainite, muriate of potash, and nitrate of soda may be named, when freely used make the soils compact has been pointed out (370,*b*,*c*). The use of these fertilizers also increases the tendency to formation of a crust at the surface. If such a crust be broken up by cultivation or hoeing, it forms again after the next rain. It is practically impossible under these circumstances to keep the soil in suitable tilth. The use of lime in connection with such fertilizers will prove an effectual preventive of crust formation. In European agriculture air-slaked lime is generally employed in connection with nitrate of soda or potash salts.

386. *On what soils will application of lime prove beneficial?* — There are three leading methods which may be followed in attempting to determine whether the soil of a given locality or the soil of a particular field needs lime. These are : (*a*) Chemical analysis ; (*b*) A study of the natural indications ; (*c*) Special tests and experiments.

(*a*) *Chemical analysis* — It is held by some authorities that every soil should contain at least 0.2 to 0.3 per cent. of lime. If chemical analysis shows a soil to contain less than the lower of these percentages, liming is believed to be called for. It is not denied that soils containing somewhat less than .2 per cent. of lime may give good crops of certain kinds, but simply that if they have less than this they will give uncertain results with some crops; as, for example, clovers. It is not the belief of the writer, however, that chemical analvsis to determine whether lime is called for will usually be necessary.

(*b*) *Natural indications* — The best natural indication as to whether lime is probably needed is afforded by the character of the spontaneous

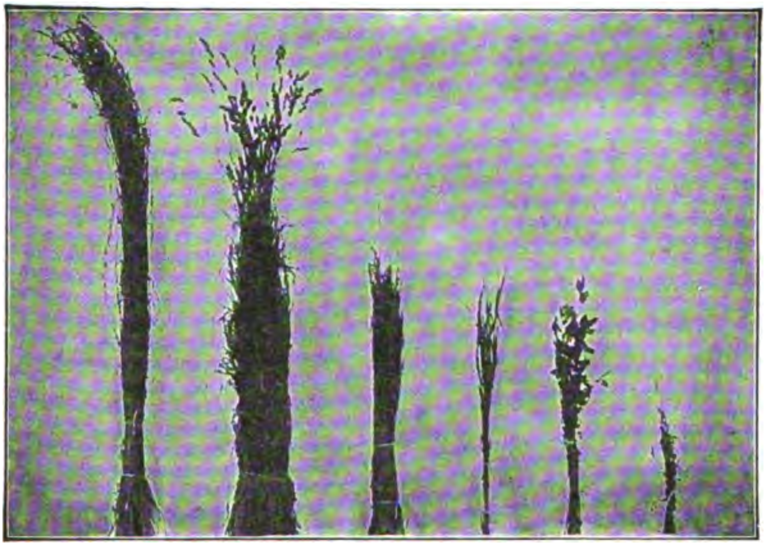


Tall Meadow Oat Grass. Orchard Grass. Awnless Brome-Grass. Common Sorrel. Miscellaneous Grasses and Weeds.

FIG. 73. GRASSES AND WEEDS. *Unlimed.* Soil sour. Plot 12, Nitrogen in Sulfate of Ammonia (1898). *By courtesy of Rhode Island Experiment Station.*

vegetation. Plants need very different amounts of lime. We have lime-loving and lime-hating plants. Among the former are vetches, red and other clovers, and when these are naturally abandant in grass lands lime is probably not required. Among trees the oak, beech, and locusts are lime-

lovers, and when these grow spontaneously and attain good size in a neighborhood it is an indication that the soil is rich in lime. On the other hand, sorrel is one of the commonest of those plants which thrive where there is little lime. It should not be concluded that where we see only here and there a few plants of sorrel lime is required, but simply that where this plant tends to come into mowings, crowding out the grass and clover and making the fields in June actually red, lime is almost certainly needed.



Tall Meadow Oat Grass. Orchard Grass. Awnless Brome-Grass. Timothy. Clover. Common Sorrel.

FIG. 74. GRASSES AND WEEDS. *Limed.* Plot 12, Nitrogen in Sulfate of Ammonia. (1898).
By courtesy of Rhode Island Experiment Station.

(*c*) *Special tests and experiments* — The use of litmus paper. Take a small sample of moist soil from the field and without touching the paper with the fingers place a piece of blue litmus paper on the soil. If the soil contains much free acid or is sour this paper will quickly turn red, and when this is the result of such tests the soil will almost certainly be benefited by liming.

The ammonia test. Put a few drops of common ammonia water in a glass holding about a teacup of pure water. Into this stir a teaspoonful of

the soil to be tested. If the soil contains any considerable excess of carbonate of lime or magnesia the water standing above the soil after it has settled and stood for a few hours will be clear. If the soil needs lime, on the other hand, it will have a darker, reddish brown or black appearance, the depth of the color depending upon the amount of soil taken and its need of lime. This change in the color of the water is due to the formation of a compound of ammonia and some of the acids in the soil.

The experimental test. Select two small plots of land in a part of a field which is apparently uniform in the character of its soil, leaving between the two a strip of land a few feet in width. A convenient size for the plots, according to Wheeler, is 13½ by 27 feet. To one of the two plots apply, says Wheeler, 41 pounds of lime, which is at the rate of 2½ tons per acre. This should be thoroughly mixed with the soil. Next apply an equal amount of fertilizer containing all the ordinary elements of plant food to each plot, and plant both. One of the best crops for this use is the beet, and an equal quantity of seed should be planted on each plot. The seed will generally germinate equally well on both plots but if the soil needs lime many of the plants will die very young on the plot to which no lime has been applied, while the other will make a good growth. This method of determining whether a soil is in need of liming is doubtless the safest which can be employed. Other crops selected from the list of those usually benefited by liming may of course be used in this experiment if preferred.

387. *Fertilizers which may be used to supply lime.*

(*a*) *Superphosphates* — Superphosphates, as has been pointed out (362, *a*), contain considerable land plaster, which is a salt of lime. These may be useful as a source of lime when that element is needed as plant food, and the plaster in them may have some of the chemical and physical effects produced by lime; but it will not be effective in sweetening sour soils.

(*b*) *Natural phosphates* — All the natural phosphates, including bone in the various forms and the fine ground rock phosphates, it will be remembered, contain a great deal of lime in combination with phosphoric acid as three-lime phosphates. The application of such phosphates may lessen the

acidity of the soil because a part of the soil acids, as has been pointed out (362, *a*), may combine with a portion of the lime, thus becoming harmless. Such phosphates, therefore, may help to sweeten sour soils, but they cannot produce the other useful effects of liming.

(*c*) *Basic slag* — It will be remembered that this contains a large amount of lime in the four-lime phosphate. A portion of this lime may combine with the soil acids, thus helping to sweeten sour soils (361).

(*d*) *Wood ashes* — These commonly contain about 35 per cent. of lime together with considerable magnesia and potash. All these elements may be useful in helping to sweeten a sour soil, and they will have, to a considerable degree, the beneficial chemical and physical effects described (369, *a*). At current prices the lime in wood ashes costs more than lime in some other forms.

(*e*) *Leached wood ashes* — Such ashes contain relatively less potash and more lime than unleached, and they may be fairly effective for most of the purposes for which lime is employed.

(*f*) *Limekiln ashes* — If wood is the fuel employed in burning lime, such ashes, which will contain relatively more lime than common ashes, may prove very useful for application to soils which need liming.

(*g*) *Gas house lime and dye house lime* — Lime which has been used in gas or dye houses is commonly wet and difficult to spread. Owing to the large amount of water they contain, transportation costs heavily in proportion to value. Gas house lime requires exposure to air before being used, as it often contains harmful compounds. These forms of lime are less effective than the lime in ashes and in many other substances. They can be used to advantage only near the places of production.

(*h*) *Fine-ground limestone or oyster shells* — Lime in these forms, if obtainable at low cost and very finely ground, may prove useful. They are most effective upon the lighter soils but are not equal to burnt lime upon the heavier soils.

(*i*) *Land plaster* — This, as has been pointed out under superphosphates, is sulfate of lime. It is manufactured from the mineral gypsum which is simply ground fine, to fit it for agricultural use. Plaster is not

equally beneficial with quicklime or air-slaked lime for the sweetening of sour soils but it may have most of the other effects of lime, as has been pointed out under (*a*).

(*j*) *Marl*— It will be remembered (82) that marl contains a large proportion of carbonate of lime. This is the same compound which is formed in air-slaked lime and the application of marl has very similar effects to those which follow the use of air-slaked lime. The clay usually mixed with the carbonate of lime, moreover, will in itself benefit the lighter soils. When these soils, therefore, need liming, marl, if it can be readily obtained, should be employed.

(*k*) *Quick or burnt lime*— This is the form of lime used by builders, but as put up in casks for builders' use the cost is relatively high. It should, if possible, be obtained direct from the producers or wholesalers. In putting up lime for builders' use the burnt lime as it leaves the kiln is handled with forks. All pieces which will lie on the fork are put into the casks but the fine lime and the pieces small enough to pass between the tines, since they will slake within a short time, are not regarded as suitable for builders' use. Such fine lime is designated "forked lime" and if this can be obtained reasonably fresh it is excellently adapted for farmers' use. It is sometimes practically all quicklime and will slake as perfectly as builders' lime. The price at which forked lime can be obtained makes it particularly desirable. Quicklime acts more energetically than any of the other forms and is the best kind of lime for soil improvement. It should be slaked either by exposure to air and weather or, better, with water; and after slaking it should be immediately spread. After lime has been slaked it will be found best to allow it to stand for one or two days and it is advisable to screen it for the removal of lumps before application. Care should be taken in slaking not to use water in too large quantities lest it become pasty, in which form it could not be spread. The quantity of water required cannot be definitely stated, since different samples of lime vary. As a rule from two to two and one-half pails is enough for a cask.

(*l*) *Air-slaked lime*— This is produced when quicklime is long exposed to damp air. It can often be purchased at limekilns, being produced by

the action of the air on the fine lime which has just been described (*k*). It can also sometimes be purchased from dealers or builders who have had it slake while in storage. Air-slaked lime often contains some lumps of imperfectly slaked lime, or, when bought from limekilns, pieces of imperfectly burnt lime. Before purchasing it should be understood that the last should be screened out as they would have no value to the farmer. Lumps of burnt lime should be screened out before applying air-slaked lime because should seed come in contact with them in the soil, where they would take up moisture and slake, its vitality would be destroyed. If, however, such lime can be applied some time before planting the seed and the soil thoroughly harrowed after the lumps have had time to slake, screening will be unnecessary. The air-slaked lime which has been long exposed to the air is in the form of carbonate and its action upon the soil is less effective than that of freshly slaked burnt lime. If this form of lime is employed larger quantities are required than of burnt lime.

(*m*) *Lime which contains magnesia* — Quicklime, air-slaked lime, etc., sometimes contain considerable quantities of magnesia in the form of carbonate. Such lime is nearly if not quite as effective as that which is more pure. There need be no fear that magnesia will injure either crop or soil.

388. *Season for applying lime* — Since the benefits of liming are mainly due to some special effect upon the soil, it will be found best to apply the lime some little time before the field is to be planted. The autumn is in most cases the best season although early spring will answer. If manure or fertilizer containing ammonia or organic nitrogen is to be used in connection with lime, the latter should be put on and mixed with the soil by plowing or deep harrowing before the manure or fertilizer is applied. If either of these should be spread first and lime should be later applied in such a way as to come into contact with them, there would be loss of ammonia. The crop which is to follow, as well as the time of year, should be considered. Lime should by preference be applied just before one of those crops which have been mentioned as particularly benefited by it is to occupy the land. Liming should not immediately precede a crop of

potatoes (382, *d*) or sugar beets. Liming is especially beneficial just before a crop belonging to the Leguminosæ, such as clovers, alfalfa, peas, and beans.

389. *Quantity of lime to be used* — Lime is applied in widely varying amounts from a few hundred pounds to several tons. Less than one ton to the acre of quicklime will commonly not be sufficient to effect much improvement if the soil is sour or for any other reason stands much in need of liming. Smaller quantities will answer for light soils than for the heavy ones. For the lighter soils 1000 to 3000 pounds per acre is the usual range. If air-slaked lime is used it should be employed in from one and one-half to two times the above named amount.

390. *Frequency of application* — If the lime be used in such quantities as have just been named, it is unlikely that an application will be required oftener than once in from five to seven years. Soils which have been long neglected may at first be benefited by more frequent liming.

391. *Method of applying* — In most cases it will be found best to plow the land, then to spread the lime as evenly as possible broadcast, and to work it in deeply with disc or other deep working harrow. On old grass land on which there is an abundant growth of moss it is sometimes regarded as best to spread a part of the lime before plowing, in order to secure more energetic action upon the vegetable matter. Lime can be spread by the use of a shovel from cart or wagon but the work is very disagreeable on account of the large amount of fine lime which fills the air. Lime-spreading machines have been so far perfected that they do very good work. Stevens's fertilizer distributer applies lime which is free from lumps evenly and satisfactorily. The tendency of the lime to fly into the air can be in large measure prevented by attaching an apron of burlap, which should reach close to the ground, to the back side of the machine.

392. *Salt* — Salt is chlorid of sodium. It was formerly much more used as a fertilizer than now, and the crude potash salts which contain considerable common salt (370, *b*) and the muriate of potash may have somewhat similar effects. Much has been claimed for salt, but its effects are not, in the opinion of the writer, of much importance. The more important among them are the following: —

1st. It helps to absorb and retain moisture and may be useful on light soils.

2d. According to Lloyd it may liberate ammonia from inert compounds.

3d. According to Storer it makes lime and potash which are a part of the compound silicates of the soil more available. The potash will doubtless be more effectively made available by the use of lime.

4th. In large quantities salt hinders decomposition, and has been used with apparent benefit in soils containing very large amounts of humus on which the growth was naturally so rank that grains tended to lodge.

5th. If used in very large quantities salt may injure or prevent plant growth. It is sometimes so used on walks to keep down weeds.

6th. Salt lessens the percentage of starch in potatoes, of sugar in beets or in fruits. This effect is due to the chlorin and is similar to that of muriate of potash (370, *c*).

393. *Soil and crop adaptation* — Salt is more likely to prove beneficial on the lighter soils, and among the crops benefited by it most are asparagus, mangolds, cabbages, and grains.

394. *Quantity and method of application* — It can seldom prove beneficial to use salt in quantities exceeding 200 or 300 pounds to the acre. It should be spread broadcast and worked in with a harrow.

395. *Sulfate of magnesia* — One of the crude salts, which come from the same locality as the potash salts, in Germany known as keserite, consists chiefly of sulphate of magnesia and this is the material generally used as the source of this substance. Magnesia is found in all crops and may sometimes be deficient in soils. This is not often the case, hence this fertilizer is unimportant save where its indirect effects are valuable. Attention has been called to the fact that it may appropriately be called "a chemical plow" (370, *e*), as it helps to render available inert food elements in the soil. Two or three hundred pounds per acre spread broadcast and harrowed in must in most cases prove sufficient.

396. *Sulfate of iron* — According to an English writer, Griffiths, and some others, this salt is very beneficial in many cases. It is claimed that

its use increases the amount of green coloring matter in the plant and that this gives it capacity to assimilate more food and therefore increases the yield. The views of Griffiths are not generally accepted and the only experiments in the Northeastern states which are known to the writer have failed to show any benefit following its use. In the opinion of the writer, this material is wholly without importance in the New England and Northeastern states, as iron appears to be abundant in practically all soils.

LVIII — FERTILIZER LAWS AND GUARANTIES.

397. *Necessity for fertilizer laws* — Since it is impossible for the farmer, by the simple inspection of a fertilizer, to tell whether it is genuine, whether it contains the elements of plant food in good amounts or not, there is clearly great opportunity for fraud, unless there be a carefully devised law for the protection of the farmer. This fact was recognized a good many years ago and all the states in the older portion of the Union now have fertilizer laws. These laws differ somewhat in different states in details. In most essentials they are nearly alike.

398. *What fertilizer laws require* — The fertilizer laws of all states require: —

1st. That the dealer shall state the percentage of each of the three principal elements of plant food — nitrogen, phosphoric acid, and potash — contained in fertilizers.

2d. The manufacturer is made liable to penalties in case the fertilizer is found not to contain the percentage of plant food guaranteed.

3d. The examination of the fertilizers and the execution of the law is usually placed in the hands of the state experiment station.

In some states the manufacturer is required to state the source from which some of the important elements of plant food come. This is most important in the case of nitrogen. It will be of use to the farmer to know whether the nitrogen comes from the nitrates, an ammonia salt, or from some organic substance. It is also important to know concerning the phosphoric acid whether it is soluble, reverted, or insoluble; and concerning the potash, whether it is present in the form of sulfate or chlorid. Prac-

tically all states require that the different forms of phosphoric acid be separately guaranteed, but no statement is required in many states as to the source of the nitrogen or potash. Concerning these the manufacturer is required to guarantee only the percentage present in the fertilizers.

399. *Different methods of expressing the guaranty* — In the interests of perfect definiteness and clearness of expression, to the end that the farmer might understand exactly what he is to expect, it would be well if all manufacturers were required to use the same form of guaranty, and it is believed that the interests of all would be equally served if the law required a simple statement covering the following points : —

1st. The percentage of nitrogen and the nature of the material from which it is derived in the case of mixed fertilizers.

2d. The percentage of soluble, reverted, insoluble, and total phosphoric acid ; and in the case of mixed fertilizers a statement of the material from which the insoluble phosphoric acid is obtained.

3d. For the potash, the percentage of actual potash ; and in the case of mixed fertilizers a statement as to the potash salt used as a source of this element.

We find, however, the following different methods of guaranteeing one and the same element :—

(*a*) *Nitrogen* — The guaranty may state percentage of nitrogen, or percentage of ammonia, or it may state percentage of nitrogen and add "equal to" or "equivalent to" a certain percentage of ammonia.

(*b*) *Phosphoric acid* — The guaranty usually gives the percentages of soluble phosphoric acid, reverted phosphoric acid, available phosphoric acid (the latter being the sum of the first two), insoluble phosphoric acid, total phosphoric acid (the latter being equivalent to the sum of the last two). To this may be added the statement "equal to" a given percentage of "bone phosphate."

(*c*) In the case of potash the guaranty usually states percentage of actual potash, but there is sometimes added such statements as "equal to" such a percentage of sulfate of potash, or "equivalent to" so much sulfate of potash.

There is no actual dishonesty in any of these forms of expression ; but they are confusing to the farmer who naturally does not perfectly understand the chemistry of fertilizers nor the relations between the different forms of guaranty. It is without doubt sometimes true that the manufacturer or dealer prefers to state the amount of ammonia rather than the amount of nitrogen, even although the nitrogen is not present in the form of ammonia, because one part of nitrogen is equivalent to more than one part of ammonia ; hence, if ammonia be guaranteed, the figure expressing the amount present is greater than if the nitrogen be guaranteed. One part of nitrogen is equivalent to about one and one-fifth parts of ammonia. If a fertilizer, then, contains 5 per cent. of nitrogen, that is equivalent to 6 per cent. of ammonia and the figure 6 makes a better showing than the figure 5. In the case of phosphoric acid, there is no doubt that the equivalent in bone phosphate is often given for a similar reason, for one part of phosphoric acid is equivalent to almost two and one-fifth parts of bone phosphate. Thus, for example, if a fertilizer contains 10 per cent. of phosphoric acid, it is equivalent to 22 per cent. bone phosphate. In the case of potash, one part of actual potash is equivalent to about one and four-fifths parts of sulfate of potash. If a fertilizer contains 5 per cent. of potash, that may be said to be equivalent to 9 per cent. of sulfate of potash. The words "equal to" or "equivalent to" as used in the case of each of the three — nitrogen, phosphoric acid, and potash — do not always mean respectively that the nitrogen is present in the form of ammonia, that the phosphoric acid is present in the form of bone phosphate, or that the potash is present in the form of sulfate. These expressions ought to have these meanings, but as a matter of fact they do not, and since this is the case their use seems likely to be misleading. The fertilizer dealer or maker should be asked, not how much ammonia the nitrogen present is equal to, how much bone phosphate the phosphoric acid is equal to, or how much sulfate the potash is equal to ; but what is the material from which the nitrogen in a given fertilizer has been derived, what the material from which phosphoric acid is derived, and what the actual material used as the source of potash.

400. *The guaranty of purity* — It is to be feared that buyers are some-

times misled by statements as to the percentage of purity of some of the unmixed fertilizers, taking this statement to mean the actual percentage of the element of plant food present in the fertilizer. A statement of the percentage of purity of a fertilizer does not give the actual percentage of an element of plant food present, but only the percentage of the compound of the element of plant food which is found in the fertilizer. A few examples will make this clear: —

"Nitrate of soda, 98 per cent. pure" means that the material contains 98 per cent. of nitrate of soda, not 98 per cent. nitrogen. Such a fertilizer contains from 15.5 to 16 per cent. of nitrogen.

High-grade sulfate of potash may be spoken of as "sulfate of potash, 90 to 95 per cent. pure," which means that it contains from 90 to 95 per cent. of pure sulfate of potash, the balance being impurities of some sort. This fertilizer would contain from 48 to 51 per cent. of actual potash.

The muriate of potash commonly sold in our markets is "80 to 85 per cent. pure" and contains from 50 to 52 per cent. of actual potash.

401. *How to interpret a guaranty* — All fertilizer manufacturers and dealers, in stating the percentage of the different plant food elements contained in their fertilizers, as a rule, give two figures; as for example: nitrogen, 3 to 3.5 per cent.; phosphoric acid, 6 to 8 per cent.; potash, 4 to 5 per cent., etc., etc. Owing to the difficulty of obtaining a perfectly even mixture in the case of a material so bulky as most of our fertilizers, such a form of statement may be necessary. In the case of the most reliable manufacturers and dealers, the actual amounts of the several elements of plant food present not infrequently equal and, rarely, even exceed the higher of the two figures given. It is not safe to count upon this. The buyer has no remedy if the fertilizer contains the minimum amount specified, and it is self-evident, therefore, that in determining the value of a fertilizer this is the figure upon which an opinion should be based.

Since, as has been pointed out in paragraph 399, the amount of any one element is not infrequently expressed in different ways, the buyer will find it convenient to have on hand figures enabling him to convert the one form of expression into the other. This will be particularly necessary in case

the farmer desires to compare fertilizers from different sources, of which the guaranty is in different form. The following table quoted from Voorhees gives the figures which may be used in multiplying, in order to convert the one form of expression into the other : —

To convert the guaranty of	into an equivalent of	Multiply by
Ammonia,	Nitrogen	0.8235
Nitrogen,	Ammonia	1.214
Nitrate of soda,	Nitrogen	0.1647
Bone phosphate,	Phosphoric acid	0.458
Phosphoric acid,	Bone phosphate	2.183
Muriate of potash,	Actual potash	0.632
Actual potash,	Muriate of potash	1.583
Sulfate of potash,	Actual potash	0.54
Actual potash,	Sulfate of potash	1.85

To show the use of this table attention is called to the following examples : Nitrate of soda is guaranteed by a prominent manufacturing company 18 to 19 per cent. ammonia. To find the percentage of nitrogen multiply the smaller of these figures, 18, by the factor 0.8235 and we have the result 14.8, which is the percentage of nitrogen contained in nitrate of soda of the guaranteed composition.

Fresh ground bone is guaranteed to contain 24 to 26 per cent. phosphoric acid. Multiplying by 2.183 we have 52.4, which is the percentage of bone phosphate in such bone.

Low-grade sulfate of potash is guaranteed 48 per cent. pure. This means that it contains 48 per cent. of sulfate of potash, as has been explained. To find the amount of actual potash we multiply by the figure shown in the table, 0.54, and we have 25.9, which is the per cent. of actual potash in such a fertilizer.

402. *Trade values* — Practically all of the experiment stations in the older states of the Union publish lists giving what are called trade values. In these lists the average prices per pound at which nitrogen, phosphoric acid, and potash in different fertilizer materials have been purchased during the immediately preceding months are given. The experiment station officers, who are in charge of the execution of the fertilizer laws and under whom the analyses are made in the different sections of the country, hold

meetings yearly to determine these trade values. It must be understood that these officers do not fix the prices — they simply determine what the average prices of the different plant food constituents during the previous year have been, using for this purpose the actual and quoted prices of the different fertilizers that have been sold in the markets of the section covered by the convention. The trade values as determined for New England for the year 1911 were as follows: —

	1911 Cents per Pound
Nitrogen in ammonia salts	16.
Nitrogen in nitrates	16.
Organic nitrogen in dry and fine ground fish and blood	23.
Organic nitrogen in cotton seed meal and castor pomace	21.
Organic nitrogen in fine bone and tankage, and in mixed fertilizers	20.
Organic nitrogen in coarse bone and tankage	15.
Phosphoric acid soluble in water	4.5
Phosphoric acid reverted	4.
Phosphoric acid in fine ground fish, bone and tankage	4.0
Phosphoric acid in cottonseed meal and castor pomace	4.0
Phosphoric acid in coarse fish, bone, and tankage and ashes	3.5
Phosphoric acid insoluble, in mixed fertilizers	2.0
Potash as sulfate, free from chlorids	5.0
Potash as muriate	4.25
Potash in cottonseed meal and castor pomace	5.

A knowledge of the trade values for the different elements of plant food may be of use to the farmer in enabling him to determine whether it will be better for him to purchase plant food in the form of unmixed fertilizers at the prices on which the trade values are for the most part based, or to purchase the mixed or "special" fertilizers. Thus, for example: A "special" fertilizer recommended for corn is found to contain nitrogen 2.7 per cent., soluble phosphoric acid 2.3 per cent., reverted phosphoric acid 5.08 per cent., insoluble phosphoric acid 4.09 per cent., potash 6.7 per cent. Such a fertilizer, then, would contain: nitrogen 54 pounds, soluble phosphoric acid 46 pounds, reverted phosphoric acid 101.6 pounds, insoluble phosphoric acid 81.8 pounds, potash 134 pounds. Such a fertilizer may be offered for sale at $30. The question is, will the farmer do well to buy it, or can he do better by buying unmixed materials and putting them together? Nitrogen in the form of nitrate is the most effective form, as has

been shown (351). 54 pounds of nitrogen at 16 cents per pound cost \$8.64; 46 pounds of phosphoric acid, soluble in water, at 4.5 cents a pound, cost \$2.07; 101.6 pounds of reverted acid at 4 cents a pound would cost \$4.06; 81.8 pounds of insoluble acid at 2 cents a pound cost \$1.64; and 134 pounds of potash in the form of muriate at 4.25 cents a pound would cost \$5.70. Adding these figures, viz., \$8.64, \$2.07, \$4.06, \$1.64, \$5.70, we have a total of \$22.11. It appears, therefore, that when the trade values of the different elements of plant food in unmixed materials are as shown in the table, there will be a large saving in purchasing the materials and putting them together rather than in purchasing the "special" fertilizer at the price named.

In conclusion, attention is called to the fact that trade values have no necessary connection with farm values. Different elements of plant food may or may not be worth on the farm what they cost, according as the materials are judiciously selected and wisely used or the reverse.

403. *The selection of fertilizers* — One of the first points which must be determined by the farmer who has decided upon the purchase of fertilizers is as to whether it is expedient for him to purchase unmixed or raw materials or the mixed general or special fertilizers. Many of the arguments in favor of the use of unmixed fertilizer materials have already been given (378). In favor of the use of such fertilizers one additional point may be here stated. All of these materials have certain definite characteristics. It is easy for the farmer to become familiar with these characteristics. It is easy for him to learn to recognize a good article of nitrate of soda, muriate of potash, dried blood, dry-ground fish, etc. Deception is therefore less easy than in the case of mixed fertilizers. Against the use of such fertilizers two points may be urged: 1st. The raw materials are not so generally kept as the mixed fertilizers. In country districts it is often difficult to find them. Agents and dealers do not as a rule keep them and most of those handling fertilizers in rural districts, holding agencies for certain definite brands of mixed fertilizers, use all their influence, naturally, in favor of their special brands and strongly advise against the purchase of the so-called "raw" materials.

2d. Most of these unmixed fertilizers which the farmer has been advised to buy are far more concentrated than the mixed general or special fertilizers. It is therefore more difficult to apply them evenly and there is more danger of damage to the crop through contact with these concentrated materials than with the less concentrated mixed fertilizers. It must be remembered, however, that the lesser concentration of the mixed fertilizers is due to the fact that they contain a considerable proportion of material which has little if any value as plant food, and on this as well as on the plant food the farmer must pay the cost of handling and transportation.

In favor of using the mixed general or special fertilizers may be urged: 1st. They are supposed to be, and doubtless in many cases are, well adapted to the crops for which they are advised.

2d. They are generally kept. Agents in all rural districts keep them in stock or can procure them at short notice.

3d. They are usually in good mechanical condition and can be conveniently and easily distributed.

Against the use of the mixed general and special fertilizers it may be urged: 1st. As implied in what has been said above, it is impossible to detect whether such mixtures really contain what it is claimed they contain or not.

2d. Their use makes it impossible to give proper weight to special conditions and requirements of individual fields and crops.

3d. The use of such fertilizers fails to stimulate thought and study on the part of the farmer. He does not consider elements of plant food, but thinks of these fertilizers in terms of tons or hundreds of pounds and is not unlikely to buy that which is offered at the lowest price per hundredweight or ton.

Taking into consideration all the arguments for and against each of these classes of fertilizers which have been stated above, as well as those mentioned in "criticisms of the system of special fertilizers" in paragraph 378, it is believed the intelligent farmer must decide in favor of the purchase of raw materials, which he may then either apply separately or make up into mixtures to suit the requirements of his several fields and crops.

404. *Home mixtures* — The use of fertilizers supplying different elements of plant food, or the several elements in varying degrees of availability, will, as a rule, be found preferable to the application of any material which may be purchased by itself. The practice of making up mixtures of raw materials at home has therefore become quite general among the more intelligent farmers. It costs less to apply a mixture including all the materials which are to be used than it does to apply a number of different materials each by itself; and therefore, except in those cases where it seems best for some special reason to do otherwise, the farmer usually prefers to mix the materials bought before applying them. It may be argued that if the materials are to be put together why not then use the mixtures made by the fertilizer manufacturers rather than to take the trouble to purchase materials and make one's own. Many of the considerations which have a bearing upon this matter have been stated; but the point which will have chief weight with the farmer is the fact that by making his own mixtures he can procure needed plant food at less cost than by purchasing the "special" fertilizers. The manufacturer's charge for rehandling the materials, grinding, mixing, and rebagging, averages, according to Voorhees, about $8.50 per ton. The cost of these operations is largely saved by the farmer who makes his own mixtures. True, he has the labor of putting the materials together and mixing them, but this can often be done at a time when otherwise the men employed on the farm could find little profitable employment; and according to the experience of many practical men the cost seldom exceeds $2 a ton, and is often considerably less. The writer has seldom obtained a quotation on a "special" fertilizer that did not exceed the cost of the same amount of plant food in unmixed fertilizers by at least $6, and not infrequently the plant food in the ton of "special" fertilizer will be found to cost from $10 to $12 more than the cost of the same amount of plant food in unmixed materials, such as nitrate of soda, dried blood, acid phosphate, and the potash salts. Voorhees says that the saving in cost by the purchase of materials and making home mixtures usually ranges from 25 to 50 per cent. Such a saving is clearly worth making; and it is quite within the reach of the farmer who will

intelligently study the subject and give the matter careful thought and consideration. It is only fair, however, to the dealers in "special" fertilizers to add that the lower cost of the plant food when raw materials are purchased is in part due to the fact that the trade in these materials is very largely on a cash basis, while that in ready mixed general or special fertilizers includes a large proportion of credit transactions.

Another of the more important of the reasons why the purchase of raw materials and the making of home mixtures is expedient must be here restated, viz.: that the home mixture may be adapted to the special conditions of the field on which it is to be used ; the nature of the soil, its previous manuring, its special requirements, and the special needs and requirements of the crop to be grown on it can all be taken into consideration. The home mixture may, therefore, be made to suit the conditions under which it is to be used better than it is probable that a mixture made for general use will suit those conditions. The making of home mixtures of fertilizers is a common practice among a large proportion of the more intelligent farmers of the older portion of the United States, and the matter has been made a subject of special study and investigation by the experiment stations in New Jersey, Connecticut, Rhode Island, and Massachusetts, and in these states the practice is more general than elsewhere.

405. *Methods of overcoming difficulties connected with the use of home mixtures.*

(*a*) It has been stated that in many country districts it is difficult to purchase materials. The large dealers in cities always keep them, but the individual farmer, requiring comparatively small amounts, hesitates to send to a distance on account of the trouble, cost of freight, length of time required, etc. These difficulties are successfully met in many communities by co-operation. The Granges, or other farmers' organizations, have in many instances made themselves useful in this connection. The farmers of a neighborhood may combine their orders through the medium of the Grange, or other organization, and forward to a responsible house in the nearest city. The materials are all bagged in packages of such size that the division of the material after its arrival will be comparatively easy, and

by having it come in large amounts, there is considerable saving in the cost of freight. Co-operation and combination are the rule of the present in almost all lines of business and manufacturing. By their adoption, production, transportation, etc., are reduced in cost. Co-operation and combination among farmers are more difficult. Were they possible they would be found to have similar economic advantages to those experienced in connection with other lines of business. Here is one line — the purchase of fertilizers — where co-operation would seem to be simple, and there cannot be the least doubt that it would make an important difference in the cost of fertilizers.

(*b*) The farmers should make more use of the experiment stations in their several states. The officers of these stations should be qualified from their knowledge and experience to give advice of value in connection with the selection of fertilizer materials and combinations which will be suitable for use under different conditions, and these officers will be found not only willing but glad to come into touch with the farmers and to help them in this direction in so far as may prove possible.

406. *The selection of materials for home use* — The points which should be most carefully considered in deciding which of the numerous fertilizers furnishing respectively nitrogen, phosphoric acid, and potash to purchase are: cost of the plant food, and its degree of availability. The cost of the plant food in different fertilizer materials is determined by the relative supply and demand. It may not bear any direct relation to the actual farm value. The price of the different materials is subject to variation from year to year and they do not all vary equally nor always in the same direction. For example, in years following a very successful fishing season dry-ground fish may be a cheap source of nitrogen, but in years following a poor season the nitrogen in it may cost much more. Before selecting fertilizers the farmer should send for quotations on all the different materials which he judges might be suited to his needs. The quotations will be in terms of so many dollars per ton. If the fertilizer is one which contains only a single element of plant food it then becomes a very simple matter to determine the cost per pound of that element of plant food in the material at the

quoted price. Let us take a few examples. In January of this year (1901) the writer received the following quotations: —

Nitrate of soda,	$42
Sulfate of ammonia,	$65
Dried blood,	$35

The guaranteed composition was nitrate of soda 15.75 per cent. One ton, therefore, contained 315 pounds of nitrogen at $42 a ton. The cost of a pound of nitrogen, then, in the nitrate of soda, was 13.3 cents. Sulfate of ammonia was guaranteed to contain 20 per cent. nitrogen. One ton, therefore, contained 400 pounds. The cost of one pound, at $65 a ton was 16.3 cents. The dried blood was guaranteed to contain 10 per cent. nitrogen. One ton, therefore, contained 200 pounds, and the cost of one pound of nitrogen at $35 was 17.5 cents. As between these three materials it should not take the farmer long, in the light of the statements which have been made concerning the relative efficiency of the nitrogen in these different fertilizers, to decide which it would be best economy for him to use, unless there is some special consideration which renders the use of this material inadvisable. If a fertilizer contains two elements of plant food, then the element which is present in least amount should be valued at the figure shown in the list of trade values; its total value should be subtracted from the cost per ton, and the cost of the principal element of plant food obtained in the manner just shown.

It is, then, comparatively easy in the case of materials furnishing one or two elements of plant food and in approximately similar conditions of availability to decide which of two materials it is best to buy. In case the availability of the elements is different in the different materials under consideration, then the nature of the soil and the crop must be considered in deciding which of two materials to select. If the soil is very deficient in fertility, and the crop one which makes an early and rapid growth, then the fertilizers used must contain the elements of plant food in highly available form. Materials containing them in that form must be taken, even although a a pound of plant food costs somewhat more.

407. *Selection of sources of nitrogen* — The following general rules re-

garding the selection of materials which are purchased as sources of nitrogen should be found useful: —

(*a*) For crops which make their chief growth early in the season, while the weather is still comparatively cool, or for such as have only a short period of growth, nitrate of soda is the best nitrogen fertilizer; although it is evident that for crops having a short period of growth, which comes after the weather has become hot, slower acting nitrogen fertilizers may be used, such for example as sulfate of ammonia or organic nitrogen fertilizers, provided they can be applied some time before the crop will need them.

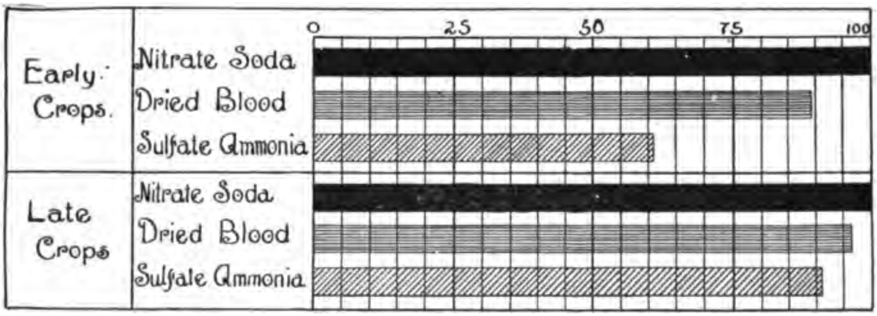


FIG. 75. The relative yields on equal amounts of nitrogen supplied in the materials named. Average of three years. Field C. *By courtesy of Hatch Experiment Station, Massachusetts.*

(*b*) For crops which have a long period of growth, occupying the ground from early or mid-spring until late summer or early autumn, it will usually be found best in making a home mixture to include, as sources of nitrogen, materials of differing degrees of availability. For such crops the nitrogen may be derived in approximately equal amounts from nitrate of soda, sulfate of ammonia, dried blood, and tankage or dry-ground fish. Cottonseed meal is another material which might be substituted for tankage or fish. This rule is to be followed only in those cases where it is desired to apply all the nitrogen which is to be given the crop at one time, usually when the crop is planted. The low cost of nitrate of soda as compared with other nitrogen fertilizers may make it preferable to depend exclusively or more largely upon this as the source of nitrogen, putting it on at two or more different times (351).

(*c*) In making home mixtures avoid using sulfate of ammonia with materials containing chlorin, such for example as muriate of potash or kainite (350).

(*d*) Avoid also putting any of the organic materials which furnish nitrogen, such as blood or dry-ground fish, with lime or ashes, as this would cause a loss of ammonia.

(*e*) Where a fertilizer is to be used as a top-dressing for grass lands, it is believed that it will be expedient to depend chiefly upon nitrate of soda or sulphate of ammonia; where an immediate result is required on nitrate of soda. If such materials as blood, fish, or tankage be spread on grass lands, there is a possibility of a loss of some nitrogen in the form of ammonia. There can be no such loss in the case of nitrate of soda or sulfate of ammonia. If in a given fertilizer mixture designed for use on one acre of land the farmer decides that 60 pounds of nitrogen is desirable, then for a crop having a long period of growth it is believed the following selection of materials will give good results: —

Nitrate of soda, 125 lbs.,	furnishing	19	lbs.	of	nitrogen.
Sulfate of ammonia, 100 lbs.,	"	20	"	"	"
Dried blood, 125 lbs.,	"	13	"	"	"
Tankage or dry-ground fish, 100 lbs.,	"	8	"	"	"

408. *Selection of materials to be used as the source of phosphoric acid.*

(*a*) In the case of crops having a short period of growth phosphoric acid should be furnished chiefly in the soluble form, as in acid phosphate.

(*b*) For crops having a long period of growth it will generally be found expedient to use materials which will furnish phosphoric acid in three forms: soluble, reverted, and insoluble. The proportion of the latter should be smaller as a rule than that of the other two, and it should be borne in mind that it is safe to depend exclusively upon acid phosphate, since the phosphoric acid applied in this form is not subject to waste. The only reason why materials containing more reverted or insoluble acid should ever be selected is that the cost of the pound of phosphoric acid may be less. Example: If the farmer decides that he needs in a home mixture for application to an acre materials which will furnish about 62 pounds of phos-

phoric acid, then he might find it expedient to use acid phosphate 200 pounds, furnishing about 24 pounds phosphoric acid; tankage 100 pounds, furnishing 14 pounds phosphoric acid; fine-ground bone 100 pounds, furnishing 24 pounds phosphoric acid.

409. *Selection of potash* — In deciding what potash fertilizer to use the nature of the soil, the crop, and the season when it can be put on should be considered.

(*a*) If a soil is believed to be in need of alkalies, then ashes may appropriately be used, but it will not generally be expedient to put ashes into home mixtures with such other fertilizers as we have under consideration. They are better put on by themselves.

(*b*) If a soil is light, and at the same time not deficient in lime, then muriate of potash may well be chosen.

(*c*) If the soil be heavy or poor in lime, then the sulfate of potash should be selected.

(*d*) For crops which are valuable in proportion as they contain more starch or sugar, potash fertilizers which contain no chlorin should be selected. The same rule should be followed for tobacco.

(*e*) If the potash can be put on early, as, for example, in the fall preceding the season when the crop is to be grown, the muriate should be used, and as this is the cheapest source of potash the farmer might often effect a saving by such timely application (370, *c*).

It is not essential to use more than one material as a source of potash in making a home mixture.

410. *Practical hints on making home mixtures* — In ordering raw materials be particular to specify that you would like the materials in good mechanical condition, free from lumps. Nitrate of soda and the potash salts (being imported and coming by ocean freight) are not infrequently quite lumpy on arrival in this country. It will often pay a farmer to have these materials reground before they are shipped. Under the best conditions fertilizer materials are likely to be somewhat lumpy. It will be found good policy to break these lumps in part in the bag. This can usually be done by pounding. Such lumps as cannot be broken in the bag had best be broken

before the materials are mixed. When ready to mix, spread in thin layers on a hard, smooth surface, putting on one material after another in regular succession and in the proper proportions. After this has been done the materials should be shoveled over several times until the whole mass is a homogeneous mixture. As a rule it will be found best to make home mixtures only a short time before they will be used, for some of the materials which are likely to be put together may attract moisture and the mixture may cake and form lumps within a comparatively short time which it will be difficult to break. Where home mixtures are to be made in large amounts it would undoubtedly be found profitable to use screens for removing the lumps and hand or power mills for grinding. Very convenient hand mills are in common use in Germany and might easily be imported, though without doubt should there be a considerable demand for them they would be made here of better quality and cheaper.

411. *Methods of applying fertilizers*—It is highly important in the case of materials so concentrated as most commercial fertilizers that they be evenly distributed. This is particularly essential in the case of home mixtures, for which, as a rule, only the most concentrated materials are used. It is believed that it is generally best to keep fertilizers containing plant food constituents largely in soluble form near the surface. From the moment of application the tendency is for such soluble constituents to work downwards with the water which percolates through the soil. It seems best, then, to start with the materials near the top. Under intensive farming and where the soil can be brought into a high state of fertility, which is the best farm practice, it is believed that it will generally be found best to apply fertilizers broadcast, spreading them evenly either by hand or by machine after plowing, and working them into the surface soil with a harrow. In the case of some of the more insoluble materials, deeper mixture with the soil may be expedient, and such materials may be either plowed in or worked in deeply with a disc harrow. There are on the market a few broadcast fertilizer distributers which will put on materials that are fine and dry more evenly and more cheaply than the work can be done by hand. In case the soil is very deficient in plant food, and when the quantity of fertil-

izers which the farmer is inclined to use is small, it may be preferable to use the materials in the hill or drill. This course may also be advisable in the case of crops which have comparatively few roots not spreading broadly throughout the soil. Numerous experimenters have found that with the potato, even in the case of soils which are in a good state of fertility and where fertilizers are used quite liberally, better results are often obtained by the use of all or a considerable portion of the fertilizers in the drill. In case fertilizers are to be applied in the hill or drill, it is highly important that they be free from lumps and that they be somewhat broadly scattered. With the concentrated materials used in home mixtures, especially, it would be a great mistake to drop the fertilizers in a bunch in the hill or in a narrow line in the drill. If in the hill, it should cover a circle 15 to 18 inches in diameter; if in the drill, it should be spread the full length of the drill and should cover a strip from 12 to 15 inches in width at least. Should seed come in contact with lumps of concentrated fertilizers, or should such fertilizers be dropped in bunches or in narrow lines in close proximity to seeds, serious injury is likely to follow. To insure more even distribution and to more certainly avoid injury to seed, some farmers and gardeners make it a practice to dilute fertilizers with dry earth, usually taking the necessary amount from the field where the fertilizer is used. Such a practice will of course much increase the cost of application and with care in applying the unmixed fertilizers no serious results will follow, so that such mixture with earth can seldom be advisable. The general advice has been given to harrow in fertilizers which are applied broadcast. It is important to recognize that this is not essential in the case of many fertilizers which farmers now use. Fertilizers such as nitrate of soda, the potash salts, sulfate of ammonia, and superphosphates, are either wholly or largely soluble. There is no danger of loss if they be left on the surface. The soluble constituents will soon wash into the soil. Mixture with the soil may, however, bring any materials of this class more quickly within reach of the roots of the crop, and in the case of organic nitrogen fertilizers and those which are mostly insoluble such mixture should always be the rule. Whether or not the nitrogen-containing fertilizer used should all be applied at the time the seed is planted

may depend largely upon the character of the soil. If the soil is of fairly retentive quality such application may be safe, but if it is of a very light, sandy character it may be safer to make fractional applications, especially if a soluble nitrogen fertilizer such as nitrate of soda and sulfate of ammonia be used. When such fertilizers are applied as a top-dressing after the crop is started it is necessary to avoid application when the leaves are wet, for when this is the case the fertilizers will adhere to the leaves in such quantity as to seriously injure them. When the leaves are dry such materials may be applied in reasonable amounts with little risk that any injury to the leaves will follow.

LIX — EXPERIMENTS AS A MEANS OF DETERMINING WHETHER FERTILIZERS MAY BE PROFITABLY USED.

412. *Necessity for such experiments* — It has been again and again pointed out that the conditions of individual fields differ, and that fertilizers can be most profitably used only when the farmer has some definite knowledge as to the peculiarities of his own soils and as to the needs of the different crops on these soils. How this knowledge can be obtained is therefore an important question. It is believed that every farmer should experiment for himself. Conditions vary so infinitely that no invariable rules can be given for the selection of fertilizers. The experiment stations may help; their officers should be able to give valuable advice, but they cannot know the peculiarities of individual cases. The conditions of the farmer's life are not favorable to the carrying out of experiments having for their objects the establishment of scientific truths (such experiments should be left chiefly to the experiment stations); but it is possible for even the busy farmer to conduct a simple experiment with fertilizers which shall shed important light upon the many problems connected with their selection and use.

Plan for Farmers' Experiments with Fertilizers.

413. *Selecting the location* — It is highly important that the location selected for an experiment with fertilizers should possess a soil of even quality throughout the entire area. It is best that the spot selected be level, but if such a spot is not available then a plot of land sloping uniformly

in one direction may be taken; but the less the slope the better. Since the quality of soil is likely to be better toward the lower than on the upper portion, it is best that the plots when laid out upon slopes should run up and down the slope and not across it. If laid out across it the plots on the lower part of the slope are likely to be naturally richer than those farther up. If the object in view in making the experiment is to obtain as much light as possible upon the natural peculiarities of the soil or upon the special influence of different fertilizers on the crop, then it is best that the spot selected for the experiment shall be rather low in fertility, and land which has been some years in grass without manure will generally be found best. Most of the farmers of the older sections of the United States, however, follow a somewhat intensive system of culture, and such farmers wish to know whether they can with advantage use fertilizers of any kind, whether it will pay them to supplement stable or farm manures with fertilizers, and if so, what fertilizers. The market gardener who makes heavy applications of stable manure will wish to know whether there is any fertilizer which he can with advantage use in addition to the manure. The farmer who keeps live stock applies manure on many of his cultivated crops. He wishes to know whether he can with advantage use any fertilizers in connection with such manures as he has to apply, and if so he wants to know what fertilizers. Such being the facts it may usually be best in the case of farmers' experiments with fertilizers that these fertilizers be applied under conditions similar to those under which the farmer will use them, if at all. He does not so much wish to know whether the fertilizer will be beneficial on a field low in fertility; he desires to know, rather, whether it will pay to use it. Experiments to determine the variation in the natural quality of soils and the special influence of fertilizers on different crops are perhaps, for the most part, better left to the experiment station. The farmers' experiments with fertilizers should be tried under farmers' conditions.

414. *Laying out the plots* — In trying fertilizer experiments the land must in some way be divided into plots. It is believed that in farmers' experiments these plots may be indicated with sufficient accuracy for practical purposes by the rows in which most of our cultivated crops are planted and

that no special measurements which are at all difficult or complicated to take need be made. In the case of such field crops as are planted in rows about 3½ feet apart, a strip of land three rows wide (10½ feet) is well adapted to the work. If the crop is broadcasted or sown in rows nearer together, strips of the same width may with advantage be taken. It is best that the plot should be comparatively narrow and long, for with this shape there is less danger that any natural inequality in the fertility of the land on which the experiment is tried will exert a confusing influence. Since there must always be one or more plots left without fertilizer as a basis for com-

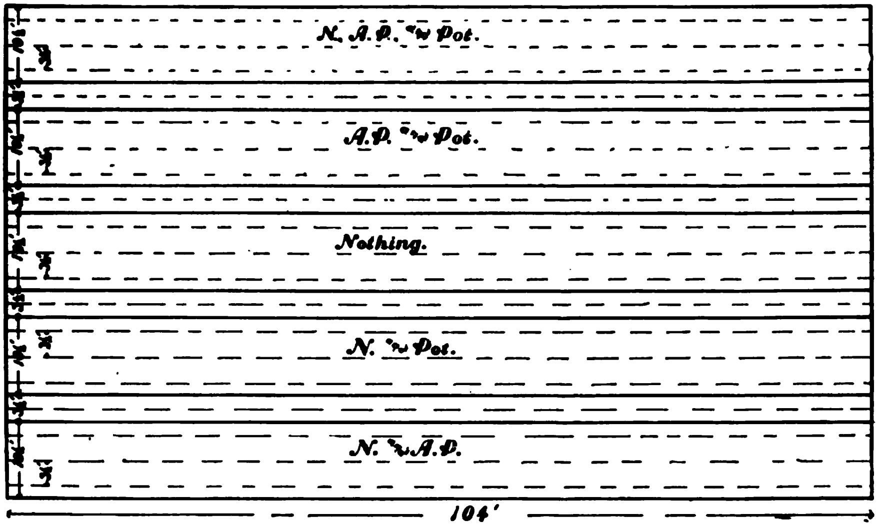


FIG. 76. Plan recommended for experiments. Full lines show boundaries; dotted lines represent the rows. N.—nitrate of soda; A. P.—acid phosphate; Pot.—potash, high-grade sulfate. Area of plots, 1-40th acre.

parison, and since the product on these plots is apt to be small, the farmer will not usually feel that he can afford to experiment on very large plots. This being the fact it is recommended that the area in a single plot be one-fortieth part of an acre. If the plots are three rows or 10½ feet wide they must be 104 feet long to give this area. The number of plots recommended for experiments of this class is at least five. The arrangement, dimensions, and fertilizers used are shown in the plan. It is not absolutely necessary

that the plots be separated by strips left without fertilizers but it is preferable that this should be the case and they are so shown in the plan.

415. *Fertilizers best suited for use in such experiments* — Any fertilizer which furnishes nitrogen by itself in available form, phosphoric acid and potash also each by itself and in available form, may be used for such experiments. It is necessary to take single-element fertilizers in order that the effect of each may be distinctly shown. As a matter of practical experience in work of this kind it has been found that nitrate of soda is one of the best materials which can be used as a source of nitrogen ; acid phosphate or dissolved boneblack as a source of phosphoric acid ; and high-grade sulfate of potash or muriate of potash as a source of potash. It is recommended that in the experiments carried out on the plan here outlined the materials used be nitrate of soda, acid phosphate, and high-grade sulfate of potash.

416. *The amount of fertilizers to be used* — In experiments of this kind any fertilizer which is used in the experiment should be used in the same amount on every plot to which it is applied. The quantity to be used should, however, be varied for different crops and the following amounts are recommended for one-fortieth of an acre : —

(*a*) For experiments with grass, cereal grains, or corn : —

Nitrate of soda,	5 pounds.
Acid phosphate,	10 "
High-grade sulfate of potash,	5 "

(*b*) For experiments with potatoes, onions, cabbages, and vegetables in general, except peas and beans : —

Nitrate of soda,	8 pounds.
Acid phosphate,	16 "
High-grade sulfate of potash,	8 "

(*c*) In experiments with clovers, peas, or beans : —

Nitrate of soda,	4 pounds.
Acid phosphate,	16 "
High-grade sulfate of potash,	8 "

(*d*) In experiments with tobacco: —

Nitrate of soda,	4	pounds.
Acid phosphate,	10	"
High-grade sulfate of potash,	10	"

417. *Method of combining and applying the fertilizers* — The fertilizers used in these experiments should always be put together as indicated in the plan, though the amounts may vary in accordance with the directions just given. There is to be one plot to which nitrate of soda and acid phosphate are applied; one to which nitrate of soda and sulfate of potash are applied; one to which acid phosphate and sulfate of potash are applied and one to which all three fertilizers are applied. This method of combining fertilizers makes it possible, as will be presently shown, to tell how many if any of the fertilizers employed have proved useful. The fertilizers designed for any one plot should be mixed just before they are needed and spread evenly over the entire plot. A man walking on the middle row of the three can easily scatter the material so as to cover the three rows, reaching about a foot and a half outside of each of the two outer ones, thus practically covering a strip 10½ feet wide. In cases where the rows are not depended upon as a guide in sowing the fertilizers, it is best to stretch two cords, one on either side of the plot. A calm day should be selected for the application of the fertilizers and it may be expedient for the sake of accurate work to take from the same plot to which the fertilizers are to be applied about an equal quantity of earth, mixing this thoroughly with the fertilizers and then spreading the mixture. The quantity of fertilizers alone is so small that even application is difficult. The greater quantity of mixed earth and fertilizers can be much more evenly spread, and the earth, if just moist enough to work freely, will be a distinct advantage in another way. It will prevent the fine, dust-dry fertilizer, such as acid phosphate or sulfate of potash, from flying through the air. It is not necessary that these fertilizers be worked into the ground. None of them will suffer loss if they remain upon the surface, but if convenient it is recommended that they be worked in with a smoothing harrow; or, if the crop is planted first in order that the fertilizers may be spread by the rows, then a cultivator or a

weeder may be run over the plots. When a harrow, cultivator, or weeder is used it is best that it be dragged lengthwise of the plots in order that the material may not be carried from one plot to another.

418. *What such an experiment may teach* — To make clear what such an experiment may teach, let us make a number of different suppositions as to the relative yield of different plots.

(*a*) Suppose the yield on plot 3, the one to which no fertilizer has been applied, is represented by the number 100; the yield on 1 is represented by 150; on 2, 160; on 4, 140; and on 5, 175. In such a case it is at once evident that each of the three fertilizers which have been used has proved useful, for if that were not the case then the yield on 5, where all three fertilizers were used, would not have been greater than on plots 1, 2, and 4, on each of which two fertilizers only were used.

(*b*) Let us suppose that the yield on 3 is represented by 100; on 1 by 100; on 2 by 175; on 4 by 175; and on 5 by 175. Then it will be evident that the potash only has been useful. Let us see how this is proved. The yield on 1, where both the other fertilizers were used but to which no potash was applied, is not better than nothing. This indicates decidedly that potash is the needed element; and the fact that the yield on 5, where both the other fertilizers were used with potash, is not better than it is on 2 and 4 is a very certain indication that nothing has proved useful in the experiment except the potash. Of course it is not to be expected that in an actual experiment the yields on 2, 3, and 5 will turn out to be exactly equal — that would not be the case one time in one hundred if each plot had been manured in exactly the same way; but, while such exact agreement in yields where any given element is the only one which is useful cannot be expected, we do sometimes in actual experiments obtain results approximately similar to those which have been supposed. Thus, for example, in an experiment on a farm in Hadley, Mass., in 1890, the yields of corn on the several plots were as follows: On the plot to which no fertilizers were applied, 20.6 bushels of sound corn (shelled), 2,830 pounds stover; on the plot to which nitrate of soda and phosphate were applied, 21.9 bushels sound corn, 2,900 pounds stover; on the plot to which nitrate and potash

were applied, 71.7 bushels of sound corn, 7,560 pounds of stover; on the plot to which phosphate and potash were applied, 60.3 bushels of sound corn, 6,340 pounds of stover; on the plot to which nitrate, phosphate, and potash were applied, 74.9 bushels of sound corn, 6,990 pounds of stover. Here we have not exact agreement, but only where potash was used was there much increase in the crop, and the increase was not much greater when all three fertilizers were used than it was when the potash was used with a single other fertilizer.

(*c*) Suppose the yield on 3 is represented by 100; on 1 by 160; on 2 by 160; on 4 by 100; on 5 by 160. Then it is evident that the nitrate only has been useful. The train of reasoning which shows this to be the case is similar to that which showed potash only to have been useful when the results were as supposed under (*b*). Here, again, it should be remembered that such exact agreement in the yields on the several plots will seldom be experienced in actual practice, but in an actual experiment with oats on a farm in Montague, Mass., in 1898, results were obtained which agree with our supposed case very closely. The yields were as follows: On the plot to which no fertilizers were applied, oats 21.5 bushels, straw 1,554 pounds; on the plot which received nitrate and phosphate, oats 31.3 bushels, straw 2,330 pounds; on the plot which received nitrate and potash, oats 30.3 bushels, straw 2,350 pounds; on the plot which received phosphate and potash, oats 23.8, straw 1,810; on the plot which received nitrate, phosphate, and potash, oats 31.3, straw 2,350. In this experiment there were other plots and on one of these the nitrate of soda was used alone, giving the yield, oats 30.3, straw 2,210 pounds. This experiment makes it perfectly evident that for this oat crop the nitrate of soda was the only fertilizer which increased the crop sufficiently to make its use profitable. It was employed at the rate of 160 pounds to the acre wherever it was used. This amount of nitrate of soda costs about $3.60. It gave, as will be seen by comparing the figures, an increase of practically 10 bushels of oats and 800 pounds of straw, which were worth about $9.00. The phosphate and potash on such land for oats would have been used at a total loss as far as the effect upon the oat crop was concerned.

Still other suppositions and the results of other actual experiments might be cited to illustrate the value of such experiments, but it is believed that enough has been said to make it clear that fertilizer experiments, carried out in accordance with the plan under consideration, may throw important light on the question as to what fertilizers, if any, can be used at a profit. Too many farmers use fertilizers without really knowing whether they are useful at all, or whether if useful at all they contain useless elements or certain elements present in too large amounts. A mixed "special" fertilizer for corn or for oats, on such land as that on which the experiments whose results have been given were tried, would have increased the crop; but it would have been used at a loss or with less profit than might easily be obtained, because it would have furnished besides the necessary elements a considerable quantity of elements which were not necessary.

419. *The important question not "what soil requires," but "what the crop to be grown requires on a given soil"* —The expression, "the soil requires this or that," is still not uncommonly met with. In the opinion of the writer the expression is misleading. The soil really requires nothing. A farmer wants to know what the crop to be grown on a soil requires. True, in some cases we may have soils so very one-sided in their composition that certain elements of plant food must be applied before they will produce crops of any kind, but this with the soils of the Northeastern states is not usually the case, and continued experiments on the same soil have shown that the requirements of different crops grown in the very same field are widely different. Thus, for example, on the grounds of the Massachusetts Agricultural College there is one field on which certain plots have been treated in the same way for twelve consecutive years. Throughout all that time one set of plots has received neither manure nor fertilizer, one plot has every year received an application of nitrate of soda at the rate of 160 pounds per acre; another plot has every year received an application of dissolved boneblack at the rate of 320 pounds per acre; while still another has had a yearly application of muriate of potash at the rate of 160 pounds per acre. To illustrate the wide difference in the require-

ments of different crops on the same land, the results for two years will be given : —

	1899. CORN. Bushels per Acre.	1900. GRASS. Pounds per Acre.
Average of nothing plots	4.6	930
Nitrate of soda plot	13.75	2,460
Dissolved boneblack	3.50	1,000
Muriate of potash	49.75	1,140

Comparison of the yields on the several plots makes it evident at once that the muriate of potash was the fertilizer chiefly beneficial to the corn and that neither of the others alone did much good. But the next year on the same plots, the crop being grass, we see that it is the nitrate of soda which proved beneficial and that neither of the other fertilizers did much good. It might be inferred from the comparison of the results on the different fertilizers that the dissolved boneblack, having been entirely useless both for the corn and for the grass, could not be required for any crop on this ground ; but this is not the case, for during two of the years since this field has been used in this experiment white mustard has been sown as a cover-crop, and this has grown with greatest luxuriance on the plot to which the dissolved boneblack has been yearly applied ; and an experiment on an adjoining field with soil of precisely the same character and with the same previous history, with cabbages and turnips, showed that the dissolved boneblack was the fertilizer which was much the most useful for these crops. We see, therefore, that on the very same field one crop requires chiefly potash, another chiefly nitrogen, another chiefly phosphoric acid. These facts, and many others which might be cited, must make it perfectly clear then that the farmer needs to experiment for himself with the crops which he grows on his own fields in order to find out what fertilizers he can use with greatest profit.

420. *Modifications of the plan outlined sometimes useful.*

(*a*) In the plan which has been given of the field for experiment with

fertilizers only one nothing plot is shown. It is sometimes a distinct advantage to have two or more such plots in different parts of the experimental field. If one of these be placed on one side of the plots to which fertilizers are applied, and the other on the other side, it gives a chance to tell with greater accuracy whether the soil was of even quality on all parts of the field; and still better might it be to have three plots to which no fertilizer is applied, one on either side and one in the middle.

(*b*) In cases where it is believed that the soil may need application of lime, another plot may with advantage be added. To this plot should be applied, first the lime, and then each of the three fertilizers used in the experiment, in the same quantity as they are used on plot 5. This will give a basis for determining whether lime is useful.

(*c*) It may sometimes be advisable, particularly in the case of the lighter soils and with crops which are not injured by chlorin, to add another plot for the purpose of comparing the muriate of potash with the high-grade sulfate. The muriate should be used in the same quantity as the sulfate, for it contains, as will be remembered, practically the same percentage of actual potash.

421. *Use caution in forming conclusions* — It should be remembered that season is not without its influence on the action of fertilizers, and further that there may be accidental conditions affecting the crops on some of the plots which cannot be controlled and which may not be suspected. With these facts in mind, the farmer should be careful not to form too sweeping conclusions based on the results of a single experiment. It is advisable to repeat an experiment a number of times before generalizing upon the results too freely. If the relative effects of the various fertilizers for any given crop are from year to year the same, then it becomes safe to generalize, but not until such results are obtained.

422. *Use your experiment station* — In this connection, attention is once more called to the fact that the officers of the various experiment stations will be glad to help in every possible way, both in interpreting results as well as in preparation for and carrying out the experiments. It is believed that in many cases the station management will be glad to furnish the ferti-

lizers put up in sacks bearing the numbers of the plots for which they are designed.

LX — DIFFERENT SYSTEMS IN ACCORDANCE WITH WHICH FERTILIZERS MAY BE USED.

423. *The best system is that based upon the knowledge obtained by experiments* — It is believed that it must have been made clear that fertilizers may be used with the best economical results only when the farmer has a definite knowledge as to the needs of crops under the special conditions of his individual case ; and it is hoped that it has been made clear how this knowledge may be obtained, and that it will without doubt pay many times over to take the necessary trouble and incur the necessary expense to carry out the experiments described for the sake of getting this knowledge. Without doubt, however, many farmers will consider this plan too difficult or complicated and for that reason some other plans will be described, any one of which is far better than no plan at all or the "hit-or-miss" system commonly followed, though inferior to the system based upon definite knowledge.

424. *A system based upon the leading plant food element required by the crop* — It is of course understood from what has preceded that every crop grown must have every one of the elements of plant food which have been stated to be necessary. But, while this is true, it is equally true in many cases that the plant or that the crop is benefited in much larger degree by some one of the important elements of plant food than by the others. It was formerly supposed that this element, which may be called the *dominant* element, must be the one which was present in the plant as shown by analysis in largest proportion, and that to determine the dominant element for a given crop it would simply be necessary to analyze the crop. This method has not been found satisfactory. It is not infrequently the case that a crop has been provided by nature with a very unusual ability to extract from the soil the element which it contains in largest amount. The dominant element for any given crop cannot be determined, then, by analysis ; it must be determined by experiment. The number of experiments with fertilizers

which have been carried out in the various parts of the world is now so great that it is possible to classify plants in accordance with their special requirements with considerable accuracy. The classification which in the writer's opinion will prove most useful as a guide in the selection of fertilizers for some of our most prominent crops is as follows: —

Crops for which nitrogen appears to be the dominant element: grasses, and all kinds of cereal grains, including wheat, rye, oats, barley.

Crops for which phosphoric acid is the dominant element: cabbages, English turnips, Swedish turnips, and all the closely allied crops of the cabbage family—cauliflower, kale, Brussels sprouts, as well as rape and mustard.

Crops for which potash appears to be the dominant element: potatoes, Indian corn, tobacco, beets, clovers, peas, beans, alfalfa, and vetches.

It will be understood from what has been said that it is not expected that it will prove expedient to use fertilizers supplying only the single element under which the crop is classed. The others are likely to be needed also; but the one under which the crop is classed should generally be supplied in especially liberal amounts; and in case fertilizers are used with manures it may often happen that materials supplying the element under which the crop is classed may be the only fertilizers that can profitably be used.

425. *System based upon stocking the soil with phosphoric acid and potash* — Under phosphoric acid and potash respectively (365 *a*, 373, 374), attention has been called to Wagner's advice to use fertilizers of each of these classes very abundantly until it is found by experiment that their further use does not increase the crop. The system now under consideration is practically the Wagner system. The method of experiment which has just been described will enable the farmer to determine when his soil has been brought into the desired condition. If there is an excess of potash in the soil then the crop on plot 1 will be equal to that on plot 5; if there is an excess of phosphoric acid in the soil then the crop on plot 2 will be equal to that on plot 5. But it should be remembered that before concluding that the soil is sufficiently stocked either with phosphoric acid or potash the farmer should experiment with a number of crops. He will de-

termine most certainly that the soil is liberally supplied with phosphoric acid by an experiment with one of the phosphoric acid crops just named; and in the same way he will determine most certainly whether the soil is sufficiently stocked with potash by experimenting with one of the potash crops just named. It should be remembered that *this system is safe* because the phosphoric acid and potash are not liable to leach out of the soil, and it should be further remembered that while it seems a considerable expense at the start, the putting of a good deal of capital into the ground, it is an expenditure which ought to prove profitable because it will do much to insure certain crops even in seasons when conditions are somewhat unfavorable. Could the crop grow uniformly from seedtime to harvest, a large yield might be expected even without an excess of plant food in the soil; but in almost every season there will be periods — longer or shorter — during which there is too little water or too much water, too high or too low a temperature, for the best growth of the crop. During these intervals the crop is making little or no progress. Then when conditions become favorable it needs to make up for lost time and it can do this only if it finds a great abundance of food within reach. Under this system the fertilizers supplying nitrogen should be for the most part of the quicker-acting varieties and the effort should be to apply them at about the time when they will be needed. It will be remembered that, after the soil has been sufficiently stocked with phosphoric acid and potash, fertilizers supplying these materials are to be used annually only in such quantities as are needed to replace the amounts removed by the crop, with perhaps a slight excess to cover possible loss. This system of using fertilizers appears to have much to recommend it. Under it all crops of the clover family will do particularly well, for these find potash and phosphoric acid in the soil in abundance, while they can take the nitrogen they need from the air. By introducing these crops into every rotation, the necessity for the purchase of nitrogen fertilizers can be greatly reduced.

426. *The system of applying the fertilizers chiefly to the money crop in the rotation* — It is the practice of not a few farmers and gardeners to apply almost all the fertilizers used to the money crops, using the manures of

home production chiefly for the other crops in the rotation. This practice is frequently a good one. On many dairy farms where corn is grown for ensilage and where potatoes can readily be sold at a good price, the following rotation is common: potatoes; corn one or two years (if one year, for the silo; if two years, the first year for grain, the second year for ensilage); the ensilage corn followed by grass and clover, which will occupy the land from two to three years; after which potatoes would be grown again on the clover sod, thus beginning the rotation over again. Under this system the potatoes would be the money crop, and fertilizers should be used liberally for this crop. The following selection of materials will suit many cases and will serve as an illustration: Per acre: —

Nitrate of soda,	200 pounds
Dried blood,	250 "
Dry-ground fish,	250 "
Acid phosphate,	500 "
High-grade sulfate of potash,	225 "

These fertilizers will supply about: nitrogen 76 pounds, phosphoric acid 90 pounds, actual potash 115 pounds. A crop of potatoes of 300 bushels per acre would take out from the soil in the tubers, which is the only part carried away, about: nitrogen 61 pounds, phosphoric acid 14 pounds, potash 90 pounds. It will be seen, therefore, that considerable of the phosphoric acid and potash in the fertilizers used for the potatoes remains in the soil to help succeeding crops. Since the crop preceding the potatoes in this rotation was grass and clover, the decaying sod is capable of furnishing considerable of the nitrogen which the crop requires (430, *b*). The crop which is to follow the potatoes is corn. This will receive an application of manure with perhaps a moderate quantity of either muriate or sulfate of potash. The potash is desirable in order to bring the land into good condition for the clover, and this crop with grass following the corn will be expected to do well without further application of fertilizers the first year. In the second year it may be found profitable to use additional potash and some phosphate, perhaps bone meal, as a top-dressing for the clover.

427. *The amount of fertilizers which may profitably be used*—In the preceding paragraphs will be found numerous statements concerning the amounts of the different fertilizers considered which it may pay to use under different conditions. It will be of use in this place to call especial attention to the fact that whatever the fertilizer the quantity which may be profitably used depends in a marked degree upon conditions.

FIG. 77. GRASS AND CLOVER, 2d year; potatoes on fertilizer and then corn on manure and potash having preceded.

(*a*) The quantity of fertilizers which may be used depends, first, on the nature of the soil. The better the physical characteristics of the soil,—the less likely it is to get into a condition unfavorable to growth, whether too dry, too wet, or too cold,—the larger the quantity of fertilizers which may be used with probable profit.

(*b*) The quantity of fertilizers which *must be used to make farm operations profitable* may be determined in part by the assessed value of the land

which is under cultivation. On land the assessed value of which is low, the farmer may obtain satisfactory economical results from soil in a lower state of fertility than must be regarded as essential if the land has a high valuation. On high priced land the culture must be intensive to be profitable, and either manures or fertilizers or both must be very freely used.

(*c*) The amount of fertilizers which may profitably be used depends very largely upon the crop. The higher the money value of the crop the more liberally may fertilizers be used. The cost of the plant food carried away in certain crops is so great that it would not pay to grow them on soils to which fertilizers supplying the full amount of plant food contained in the crop must be applied. Voorhees calls especial attention to this fact and says that crops may be put into two general groups: First, those which possess a high fertility value and which as a rule possess a relatively low commercial value; and, second, those which possess a low fertility value and a relatively high commercial value. In the first class are included the cereal and forage crops; in the second are included the various vegetable and fruit crops and tobacco. Voorhees illustrates this classification by these examples: —

"A ton of wheat at $1.00 a bushel will bring $33.33. Its sale removes from the farm 38 pounds of nitrogen, 19 pounds phosphoric acid, and 13 pounds of potash. At prevailing prices for these constituents it would cost $6.50 to return them to the farm.

"A ton of asparagus sold at 10 cents per pound bunch will bring $200. Its sale removes from the farm 6 pounds of nitrogen, 2 pounds of phosphoric acid, and 6 pounds of potash, all of which could be returned for but little more than $1.00.

"A ton of timothy hay will bring $10; its sale removes from the farm 18 pounds of nitrogen, 7 of phosphoric acid, and 28 of potash — amounts that would cost $4.

"A ton of apples will bring in an ordinary season $20. It removes from the soil less than 3 pounds of nitrogen, 1 of phosphoric acid, and 4 of potash, which would cost less than 60 cents to return to the land."

These statements make it evident that wheat and grass, having com-

paratively low commercial values, yet remove from the soil such quantities of plant food as would cost considerable to replace, while asparagus and apples, with a much higher commercial value, remove less plant food from the soil. The chance for profit on the liberal use of fertilizers is evidently much greater with crops of the latter class than with those of the first. It is further pointed out that the amount of fertilizers which should be used for a crop may wisely be varied with the labor cost of the crop. For crops involving a heavy expenditure of labor, it will not pay to run the risk of decreased yield because of insufficient supply of plant food. The cost of the labor is the chief factor with such crops, and fertilizers should be so freely used that there shall be no risk of decreased yield because of their insufficiency. Among crops of this character the onion, carrot, and tobacco may be named as prominent representatives. While the farmer must largely depend upon himself in arriving at a decision as to the kinds and amounts of fertilizers which he can profitably use, very definite advice as to the kinds and amounts which under ordinary conditions may probably be employed with advantage will be given in that section of this book dealing with the different crops (p. 400 et seq.).

LXI. GREEN MANURING.

428. *What green manuring is* — Green manuring is the name given to the practice of growing on the land a crop which is produced for the purpose of improving its condition. Such a crop may be either left on the surface or worked into the soil with harrow or plow. Very much has been said and written in recent years concerning the possible benefits to be derived from green manuring. Enthusiasts advocate depending upon it almost exclusively for the maintenance of fertility. Such individuals claim too much for it. It is under some conditions a useful practice. It often takes the place in modern times of the bare-fallow which was so common among farmers in earlier times. The Mosaic laws commanded that the fields should be given rest one year in seven. Most ancient writers have advocated this practice, and even within comparatively recent times the farmers of England have followed it extensively. It is not denied that the bare-fallow improves

the condition of the soil. It is not denied that after it the crops may be larger than before. During such time as the field is kept bare, especially if the soil is worked with the plow or harrow, those agencies of nature whose action renders the constituents of the soil available are at work and the store of plant food, in such condition that the crop can make use of it, increases. But the bare-fallow is now condemned because it is believed that the benefit is obtained at too great a cost. The labor performed upon the field during such a fallow brings no immediate return ; but more important than this, a very considerable share of the most valuable constituent of plant food gradually rendered soluble and available through the action of natural agencies during the bare-fallow is lost. The decomposition of the humus and the action of the nitric acid ferments during the bare-fallow convert no inconsiderable proportion of the nitrogen of the soil into nitrates, and these, if the soil is bare, are washed out of the soil (133). It is for this reason chiefly that, in modern times, it is recommended rather to keep the field covered with a crop whose hungry rootlets will fix nitrates as they are produced.

429. *Possible benefits of green manuring* — The benefits which may result from green manuring may be best considered under two heads : 1st, benefits connected with the store of plant food ; 2d, mechanical benefits.

1. *The plant food of the soil as affected by green manuring* — Here again we must consider separately the mineral elements of plant food and the nitrogen.

(*a*) *Mineral elements of plant food* — It will be remembered that plants take all the mineral elements of plant food from the soil (30). There is no other possible source from which these elements can be taken. It is evident, therefore, that the practice of green manuring does not make it possible to increase, in the very least, the amount of any of the important mineral elements in the soil, such as phosphoric acid, potash, lime. Nevertheless, it does not follow that green manuring may not be beneficial in connection with the mineral elements. It has been pointed out that the roots of plants excrete an acid (52) and that this acid dissolves constituents which are not directly soluble in water. Green manuring fills the soils with roots ;

the action of these roots on the mineral particles which make up the soil helps dissolve food elements ; and then, when the green manure crop decays, these food elements are more accessible to the succeeding crop than they would have been if still a part of the mineral constituents of the soil. Green manuring, therefore, increases the availability of the phosphoric acid, potash, and lime of the soil. Further, green manuring is an important means of increasing the stock of humus in the soil. Humus has numerous important physical effects (67). Where it is present in considerable amounts a soil is more moist. As it decays carbonic acid is produced and the temperature of the soil may be raised. With more moisture (within moderate limits), carbonic acid, and a high temperature, conditions are more favorable for the solution of the soil constituents. Still further, many of the most valuable green manure crops are very deep rooted. Sending feeding rootlets into the subsoil, they take up soluble elements of food which may have been leached downward. These elements are made a part of the above-ground portions of the green manure crop. This crop, therefore, may play an important part in bringing up from the subsoil, where it might be useless to the ordinary crop, soluble food which is thus placed at the disposal of the crop which follows.

(*b*) *Relation of green manuring to the nitrogen supply of the soil* — In two important particulars, green manuring may affect the stock of nitrogen in the soil ; viz., by conservation, and by accumulation.

Nitrogen conservation — In various connections it has been pointed out that the stock of nitrogen in the soil under usual conditions is gradually converted into nitrates and that these are liable to wash out of the soil (133). The most effective method of preventing this loss is found to consist in keeping the soil filled with the hungry rootlets of a growing crop. These rootlets will use the soluble nitrates, and the nitrogen in them is made a part of the green manure crop. It is locked up, so to speak, in the vegetable tissues and will remain so locked up until these tissues decay. The season when loss of nitrates is most likely to take place is late autumn : hence to prevent this loss, or for nitrogen conservation, those crops are most valuable which are not affected by the autumn frosts and which will

continue to grow as late as possible. Green manuring, for the purpose of nitrogen conservation, is self-evidently most important upon the richer soils which are light and porous in character and which have open subsoils.

Nitrogen accumulation — There is but one family of plants, and to this attention has been repeatedly drawn, whose members have the ability to take nitrogen from the air. This is the family known as *Legumes* (pod family). How they do this has been explained (133, *b*). Members of this family are frequently and not inappropriately spoken of as "nitrogen gatherers" or "nitrogen traps." Some of the plants of this family are by far the most valuable of the green manure crops ; for the increase in the amount of soil nitrogen which follows their growth must be looked upon as in most cases the greatest single benefit that can be derived from the practice of green manuring. The legume, with the assistance of its little partners (bacteria), takes the nitrogen from the air in the first instance for its own benefit, but when it decays this nitrogen becomes available to the following crop.

2. *Mechanical effects of green manuring.*

(*a*) *Mellowing and opening the subsoil* — The deep-rooting green manure crops have an important influence in mellowing and opening up the subsoil to the action of air, water, and carbonic acid. As the deep roots of these crops rot, channels through which air and water may more freely pass are left behind, and the rotting produces carbonic acid, which will help dissolve the constituents of the subsoil. It has been found that as a result of this effect upon the subsoil the following crop, even if ordinarily shallow rooted, sends its roots to much greater depth than usual. Schultz-Lupitz found that the roots of the potato, which ordinarily develop almost entirely near the surface, penetrate deeply into the ground after a crop of lupines, following the furrows left by the decay of the roots of that crop. Under these conditions, the potato proved far less liable to injury from drouth than when more shallow rooted ; and the roots, coming in contact with a much larger portion of the soil, were able to gather from it an unusually large amount of food. The crop after a deep-rooting green manure is always more certain and larger.

(*b*) *Clearing the field from weeds* — Green manuring may be made of much assistance in clearing a field from weeds. This result is a consequence of the fact that it may be made to cover and shade the ground and thus to kill out weeds of many kinds.

(*c*) *Protection from injury by washing or from wind* — At many seasons of the year our fields are particularly liable to damage from surface washing which eats out gullies in the hillsides, carrying the finer and better parts of the soil to lower levels. Such injury is most frequent in late fall, winter, and early spring. If a field can be kept covered during this season this injury may be prevented. Not infrequently during the late spring or summer, and sometimes during the winter, violent winds sweeping over the surface do enormous damage through carrying away the finest and best soil particles. This injury can be largely prevented by keeping the ground covered with a green manuring crop.

Summary. Green manuring, then, may be beneficial in the following ways: —

It may increase the availability of the mineral elements of plant food.

It may increase the store of humus and thus warm the soil.

It may save nitrogen which would otherwise be lost.

It may increase the stock of nitrogen in the soil.

It may bring soluble food from the subsoil to the surface where later crops may feed upon it.

It opens and mellows the subsoil.

It makes following crops deeper rooted and so more certain and less liable to injury from drouth.

It may help to free the field from weeds.

It may prevent injury from washing or from wind.

These benefits, as will be seen, are numerous and important. Such being the case, it will readily be admitted that the practice may prove of much value. Nevertheless, in the opinion of the writer, the conditions under which it will pay to turn under the entire crop grown as a green manure are comparatively seldom met with in most parts of the older states.

430. *Conditions under which green manuring is advisable.*

(*a*) *Green manuring crops have a food as well as a manurial value* — Most crops grown primarily for soil improvement may be said to have two values, viz., a value for food and a value for manure. The crop as it stands in the field has a certain value as a means of soil improvement — a certain manurial value. It has also, in almost all cases, a certain value as food. It may be used as a food either by pasturing or by cutting and taking it to the animals. In either case, under proper management the excrements of the animals consuming the crop will be worth as manure about three-fourths as much as the entire crop would be worth if incorporated in the soil (303). If we leave the crop in the field, then, in the one case we get its full manurial value. If, on the other hand, we feed it and carefully save and apply the excrements, or, if we pasture and so manage that the droppings are evenly distributed, we have the food value of the crop and about three-fourths of the manurial value. The sum of these two in the great majority of instances will be greater than the full manurial value. In pasturing a green manure crop, portable fences should be used if the full value of the droppings is to be realized. The animals must be successively confined to small portions of the field to give the best results. There are of course conditions under which a crop cannot be profitably fed. This would be the case on farms or gardens where no stock is kept. It may also sometimes be the case when the crop is grown in fields which lie at a great distance from the homestead. Under such circumstances the entire crop should be turned in. It is further true that on the soils where humus is particularly essential, viz., those of the lightest and most sandy type, the turning under of the entire crop may give the most satisfactory results. In the great majority of instances it is believed a crop grown as a green manure would better be fed.

(*b*) *Manurial value of roots and stubble* — It has been urged that under the conditions prevailing in the older states on the farms where stock is kept the crops may usually be more profitably fed than devoted exclusively to green manuring. In this connection it is important to point out that when the crop is fed we still have the full manurial value of the roots and stubble. This is often large. These may give us all the mechanical benefits to be derived from green manuring, while in the case of legumes they may con-

tain a considerable proportion of the nitrogen which the legume has taken from the air. New England dogma, generally regarded as sound, has it, "You can't eat your cake and have it too." In the matter of soil nitrogen we may regard this old saying as disproved. You may raise a crop of clover or clover-like plants, you (vicariously through your cow if you prefer) may eat this crop and consume enormous quantities of nitrogen, and yet in the soil upon which the crop was grown will be found more nitrogen than was contained in that soil at the outset. Is not this "eating one's cake and having it too"? The roots and stubble in one acre of clover sod are reported in one instance by Voelcker in England to have contained 100 pounds of nitrogen. Weiske in Germany found 180 pounds. Even the lesser of these amounts is greater than the quantity of nitrogen which the farmer would ordinarily think of applying in the shape of fertilizers. It will not be wondered then that good crops can be grown on clover sod. The results of an experiment upon the grounds of the Massachusetts Agricultural College are highly interesting in this connection. On one of the fields which has been under experiment for about eleven years (1901), a number of plots have received neither manure nor fertilizer supplying nitrogen throughout the entire period. The crops on the plots to which no

PER CENT. AVERAGE YIELD ON PLOTS GETTING NO NITROGEN TO AVERAGE OF PLOTS GETTING NITROGEN.

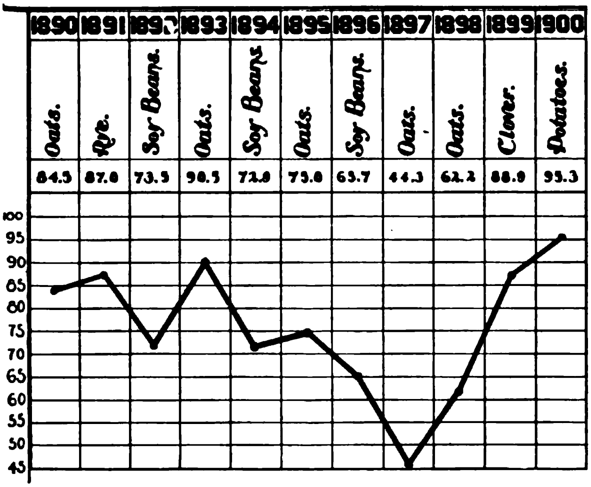


FIG. 78. Curve showing relation of average yield of plots not manured with anything supplying nitrogen to average yield of plots manured with materials supplying nitrogen. After clover in 1899, potatoes are almost as good on the no-nitrogen as on the nitrogen plots. The saving amounts to about $7.00 per acre.

By courtesy of Hatch Experiment Station, Massachusetts.

nitrogen had been applied in the years immediately preceding the growth of clover varied from a little less to slightly more than one-half the average crops produced on the plots to which nitrogen-containing manures or fertilizers had been every year applied. The clover crop of the no-nitrogen plots in 1899, which was cut twice, amounted to about 89 per cent. of the average of the plots to which nitrogen had been applied. The potato crop in 1900, grown on the clover sod, was almost as good on the no-nitrogen plots as on the others. The average of the plots to which nitrogen was applied was 219 bushels per acre; the average of the plots to which no nitrogen was applied was 209 bushels to the acre, a little more than 95 per cent. of the crop produced where nitrogen manures had been yearly applied. The cost of the nitrogen manures which gave the greater crop, 219 bushels, was at the rate of about $8 per acre. It is evident that the extra ten bushels of potatoes did not pay for this expenditure.

431. *Characteristics which should be possessed by green manure crops* — Among the characteristics which it is most important that a crop should possess to make it fit for the various uses of green manures, the more important are the following: The seed must be cheap; it must be a crop which can make good growth if sown broadcast; it should be a crop which makes rapid growth; it should have a deep and vigorous root system; it should be hardy, *i. e.*, not injured by frosts. If, in addition to the characteristics named, it is a legume and possesses the ability to gather nitrogen from the air it will prove most valuable.

(*a*) *Ability to thrive broadcast* — This is the quickest method of planting and if a crop will thrive under it, it costs least to put it in. Moreover, the crop sown broadcast most quickly and efficiently covers and shades the ground, and therefore is most effective in stifling weeds.

(*b*) *Rapid growth* — A crop which makes a rapid growth from the very start is the most effective assistant in helping to free a field from weeds. As it produces a large bulk of vegetable matter in a limited time, it may be possible to enrich a soil in humus to an extent otherwise impossible in the perhaps limited interval between the growth of crops which are to be harvested.

(*c*) *A deep and vigorous root system* — The possession of roots reaching deep and wide and filling the entire soil means that the crop will have a maximum influence in the direction of the various kinds of improvement possible from green manuring. Such a system of roots makes a crop a good *rustler*, to use the expressive Western phrase, and this is the kind of crop which the farmer needs for soil improvement.

(*d*) *Hardiness, nitrogen conservation* — The prevention of the waste of this important element is oftentimes one of the most important of the effects of green manuring. But waste of nitrogen in the form of nitrates is most common during the period of heavy autumn rains, in the climate of the Northeastern states, usually from about the 5th of November to the middle of December. The crop which continues to grow until the ground actually freezes is evidently the crop which most certainly stands ready to take nitrates as they are washed downwards through the soil.

(*e*) *Legumes best if they possess the other important characteristics* — It is self-evident that if, in addition to meeting the several requirements which have just been specified, the crop also has the ability to take nitrogen from the air this ability must add enormously to its value. Fortunately, many of the legumes meet every condition and as will be seen, therefore, we find among them the greatest number of the crops which are prized in the different parts of the world as a means for soil improvement.

432. *Crops valuable for green manuring* — Among the different crops which, under varying conditions, seem likely to prove of value in the older Northern states of the Union for green manures may be named: winter rye, buckwheat, white mustard, rape, spurry, vetches, peas, lupines, crimson clover, red and mammoth clover, sweet clover, the cow pea, and the soy bean.

433. *Winter rye* — Winter rye is one of the most useful of the green manure crops outside of the legumes. It grows until late in the autumn, and, beginning growth very early in spring, it is very efficient for nitrogen conservation. It affords cover and protection in winter, preventing both damage from wind and washing. It may be sown any time from the middle of August to the first of November, the quantity of seed varying, according

to the soil and the season, from 2 to 3 bushels. Rye is suited to light soils. Its growth in spring begins so early that, previous to the time when many of our crops must be planted, it will have made sufficient growth to furnish a large amount of humus. Many farmers sow winter rye with advantage after potatoes or in corn at the time of the last cultivation. In this manner they secure the advantages of green manuring, save that of nitrogen gathering, and without losing a harvested crop, for rye grows in the interval between successive crops.

FIG. 79. A SINGLE PLANT OF DWARF ESSEX RAPE. *After Kennedy. Bul. No. 22, Div. of Agros., U. S. Dept. of Agriculture.*

434. *Buckwheat* — This crop is suited to light and comparatively poor soil, on which it will make a more rapid growth and furnish a larger amount of humus within a limited time than most crops. It is not deep rooted, it cannot gather nitrogen, it is killed by frosts, and therefore cannot effectively conserve nitrogen. In spite of these defects, it is frequently employed as a green manure. About 1 bushel of seed per acre is required.

435. *White mustard* — This is suited to the light and sandy loams. It is distinguished for rapid growth and hardiness. It is not killed until the ground actually freezes. It is valuable for nitrogen conservation. It may be allowed either to remain on the surface as a cover for winter or it may be plowed under in November. It will make a good growth before cold weather, if put in after early potatoes or sown in corn at the time of the last

cultivation. It starts quickly, if the corn is not too thick, and will help keep down weeds. It does not itself become a weed. About ⅓ bushel of seed per acre is required, when sown in corn. Half that quantity would be sufficient if sown alone.

436. *Rape* — There are two classes of rape, viz., spring and winter. Wherever winter rape can be grown, it is a valuable green manure crop. It is hardy, like all the members of the turnip and cabbage family to which it belongs, and grows until the ground actually freezes. It begins growth very early the following spring and furnishes a large mass of green material which may be turned under in season for planting most of our crops. Winter rape is not hardy in the latitude of Massachusetts. Among the varieties of spring rape, the Dwarf Essex seems to be the most valuable. This might be sown after the harvesting of an early crop, when it would make considerable growth before winter and would prove a valuable crop for nitrogen conservation. Either the spring or the winter rape furnishes excellent pasturage for most kinds of stock.

437. *Spurry* — Spurry is not generally known to the farmers of the United States. It is prominent in European agriculture and has been grown successfully in various parts of this country. It grows with great rapidity and may be turned under in about six weeks after sowing. It thrives upon lighter and poorer soils than most crops. Spurry is not a legume and is therefore not able to gather nitrogen, neither, since it is not hardy, is it important as a nitrogen conserver. What renders it especially valuable as a green manure is its ability to thrive on soils of the lightest and poorest character, and its rapid growth. The Michigan Experiment Station reports very successful experiments in improving a light sandy soil, known in that state as the "Jack-Pine plains," by the growth of spurry. Crops of grass and wheat following spurry which was plowed in were very greatly improved. From 6 to 8 pounds of seed per acre are sufficient.

438. *Vetches* — There are two classes of cultivated vetches, viz., spring and winter. Both are valuable, and the winter vetch is hardy on all well drained soil in the latitude of Massachusetts. It is suited to medium loams, but neither the spring nor winter vetch do well without a fairly liberal sup-

ply of moisture. The vetch is a legume, and has the capacity to enrich the soil in nitrogen. The winter vetch should be sown in early fall; the spring vetch in early spring. It is best to sow grain with either: winter rye for the one and oats or other spring grain with the other. The vetch has not so vigorous a habit of growth as some of the other legumes, and on account of the hot, dry weather to which we are liable it does not promise to prove as valuble as many others. About 1 bushel of seed per acre is required.

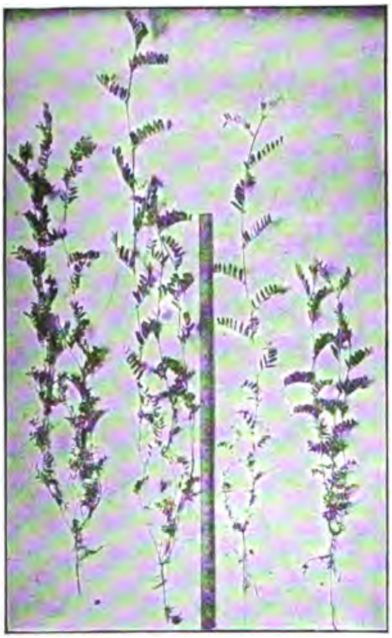


FIG. 80. WINTER VETCH. Grown with winter rye.

439. *Peas* — The various varieties of field peas do best upon medium or moderately heavy loams. They are legumes and nitrogen gatherers and sufficiently hardy so that they may serve also the purpose of nitrogen conservation. They are best sown with some grain which will furnish support to the vines. Peas require a longer season to come to maturity than many of the green manure crops; still they may prove valuable under some conditions; 1½ to 2 bushels of seed per acre are required.

440. *Lupines* — All lupines are legumes. The cultivated lupines are annuals, *i. e.*, they live but a single year. There are three distinct sorts: the white, the blue, and the yellow. Lupines do best upon the light or medium soils. They are very deep rooted but are not hardy. Under suitable conditions they make a rapid growth, and they are recognized as among the most valuable crops for the improvement of the lighter soils. The table shows the increase obtained in experiments upon a sandy soil in Germany where rye followed lupines and other legumes.

INCREASE IN THE YIELD OF RYE PER ACRE ON GREEN MANURED PLOTS OVER THOSE NOT GREEN MANURED.

KIND OF GREEN MANURE.	Date when plowed under.	Increase in Grain. Pounds.	Increase in Straw. Pounds.
Yellow lupine	Sept. 28	1,101	1,261
Blue lupine	Sept. 28	1,343	1,963
White lupine	Sept. 28	1,352	2,137
Crimson clover	Sept. 28	903	1,620
Vetch	Sept. 28	1,077	2,122

441. *Crimson clover* — Concerning no crop brought to the attention of our farmers in recent times has so much been said and written as of crimson clover. Under the right conditions, it is undoubtedly one of the most valuable green manure plants. The table just given shows a large increase in the succeeding crop due to its cultivation. In the United States there have been many successful experiments in soil improvement by this means. Perhaps in none of these were more striking results obtained than in an experiment reported by Prof. Neale of the Delaware Experiment Station. To quote from that report: "8.3 tons of crimson clover, grown from seed which cost $1.00 per acre, added 24 bushels to the corn crop; $1.00 invested in nitrate of soda, and used as a top-dressing, added 6 bushels to the corn crop. Hence, in this case $1.00 invested in clover seed returned four times as much as $1.00 invested in nitrate of soda. As to the relative amount of labor involved, the sowing of the seed and the broadcasting of the nitrate of soda possibly balance

FIG. 81. WHITE LUPINE (*Lupinus albus*). *Bul. No. 2 (rev.), Div. of Agros., U. S. Dept. of Agriculture.*

each other. Plowing down the green crop is doubtless far more costly than plowing bare ground. This drawback may reduce the above-named apparent gain 25 per cent." In the latitude of New Jersey and farther south crimson clover appears to be perfectly hardy ; farther north it is in many localities uncertain. Only in those localities where it endures the winter is crimson clover likely to prove of importance. Being a legume, this clover is a nitrogen gatherer. It is not injured by the frosts of autumn and is therefore a nitrogen conserver. It is deep rooted ; grows so early and so rapidly in spring that a large bulk of green material may be turned under in season for planting corn and other crops which are planted at about the same time. In localities, therefore, where crimson clover sown during the early autumn passes through the winter successfully, it must prove a very valuable green manure, for it can be grown between two successive harvested crops. It can be sown in corn at the time of the last cultivation and would help keep down the weeds and greatly improve the soil for the following crop. It seems to the writer improbable that crimson clover will prove of much value where it must be spring sown, for if sown at this season it cannot usually come between harvested crops—the land must be given up to it. Under these conditions it would seem to be preferable to use a crop which will make a larger growth, such, for example, as the cow pea, which is suited to similar soils. The quantity of seed needed is about 20 pounds per acre.

FIG. 82. CRIMSON CLOVER (*Trifolium incarnatum*).
Bul. No. 2 (rev.), Div. of Agros., U. S. Dept. of Agriculture.

442. *Common red and mammoth red clovers* — These clovers require rather too long a time to produce a crop to make them of the highest importance for turning in, although if the field can be given up a sufficient

length of time they are among the very best of the crops that can be used for soil improvement. Many a farmer has found by experience that if he can first make clover grow upon his soil he can then raise crops of all other kinds. As has been pointed out, the farmers of the older states will comparatively seldom care to turn under a crop which has a food value, preferring to utilize it first as food and secondarily as manure. For this especial purpose there are no crops more valuable than these clovers, for the stubble and roots on decaying largely increase the productiveness of all soils. These clovers are deep rooted, they take nitrogen from the air, they are hardy in autumn and so conserve nitrogen, they serve for winter protection of the soil. The benefit to the following crop from turning under the clover sod has been pointed out (430,*b*). These clovers, for the purpose of soil improvement, are best sown late in July, or early in August, the seed being used at the rate of about 12 to 15 pounds per acre. If sown at this time they become established before winter, and are not especially liable to heave or to winterkill. If sown at this time, they will give two good crops the following season, after which the sod, with such growth as starts for the third time, may be turned under; or, if a stock of humus is especially needed and the field is one to which it is difficult to cart manure, the second crop may be turned under. The value of the forage produced may be somewhat increased by sowing grass seeds with the clover at the same season, while the effect in the direction of soil improvement will not be essentially different. The grasses will help form a closer sod, filling in the spaces between the clover plants and thus giving a heavier yield of forage.

443. *Sweet clover* — This crop is not a true clover, the scientific name being *Mellilotus alba*, while all the clovers are *Trifoliums*. Sweet clover is very deep rooted, it is hardy in autumn and conserves nitrogen, it may serve for soil protection and it gathers nitrogen. Sown in July, it becomes well rooted before winter and is seldom injured on the light to medium loams. It starts very early in spring and grows with great rapidity. By the 10th of June it is sometimes from 2½ to 3 feet in height in central Massachusetts. Corn, especially for the silo, may often be put in from June 10 to 20 with every prospect of success, and it may be doubted whether any

nitrogen-gathering crop which can be grown throughout the Northeastern states will furnish so much green material to be turned in previous to these dates as will sweet clover. Very favorable results are reported in green manuring with sweet clover on heavy soils in Germany. The table gives the results of one experiment with oats.

YIELD OF OATS AND STRAW PER ACRE WITH DIFFERENT MANURING.

Treatment.	Grain. Pounds.	Straw. Pounds.
Without green manuring, no fertilizer	1,099	1,748
Green manuring, no fertilizer	1,645	3,381
Green manuring, 322 pounds phosphatic slag	1,901	3,186
Without green manuring, 161 pounds nitrate of soda (harrowed in)	2,723	5,003
Without green manuring, 161 pounds nitrate of soda (as top-dressing)	1,591	3,455

It will be noticed that the crop was very largely increased where the sweet clover was plowed in. Similar results have been obtained with potatoes. Sweet clover has no great value as a fodder. When young it is readily eaten by cattle, but with increased age the plants acquire a strong flavor which renders them unpalatable, and they also become tough and woody. The use of this crop, therefore, must be chiefly for soil improvement. For combined forage and incidental soil improvement, it is less satisfactory then the clovers last considered. The quantity of seed required per acre is from 20 to 25 pounds. It should not be sown later than about August 10. If so sown it is liable to heaving or winterkilling.

444. *The cow pea and the soy bean* — Cow peas require a longer season for growth than most crops which have been considered, but they may be valuable under the right conditions. The cow pea has been very highly praised in many quarters as a green manure crop. It is particularly adapted to the lighter and poorer soils. It endures drouth and hot weather exceedingly well. It takes nitrogen from the air and furnishes a large amount of green material for turning under. The cow pea forage is somewhat less palatable than green clover but is often fed green with advantage, while in the South it is sometimes made into hay. This so-called pea does not in the least

resemble the true peas, being rather a bean than a pea, and the whole habit of growth resembles that of the ordinary beans. There are many varieties, early and late. The black is one of the best of the former; the Clay, Whippoorwill, and Wonderful are among the best of the later. Even the early varieties ripen but little seed in the latitude of central Massachusetts. They require a longer and hotter season than is common in that latitude. The chief benefit which may be expected to follow the use of the cow pea as a green manure, aside from the increase in humus, must be from its ability to gather nitrogen, in which respect in the right climate and on the lighter soils it is probably not inferior to any crop which can be grown. Experiments have shown, however, that legumes of all kinds take nitrogen from the air in largest proportion as they approach maturity. Hence, the crop which matures in any given locality will enrich the soil in nitrogen to a far greater extent than one which does not mature. This being the fact, it may be doubted whether the cow pea should be selected as a means of enriching the soil in nitrogen in localities where it will not mature.

The soy bean seems likely to prove of greater value where the cow pea fails to ripen. It is adapted to about the same class of soils and produces about the same amount of vegetable matter. There are many varieties. The Medium Green suits the latitude of central Massachusetts better than any other and this variety has proved itself remarkably vigorous, free from disease, and capable of drawing nitrogen from the air to an unusual extent, its roots being most thickly studded with the nodules containing those little partners whose usefulness has been pointed out. In the Massachusetts Experiment Station, cow peas of different varieties have been grown side by side with the Medium Green soy bean on a medium loam, with results as shown in the table :—

COW PEAS AND SOY BEANS FOR GREEN MANURING.

Variety.	Pounds Per Acre.		
	Green Weight.	Dry Matter.	Nitrogen.
Wonderful cow pea	19,600	3,622	80.4
Black cow pea	20,035	3,389	62.1
Medium Green soy bean	19,685	5,386	167.3

The table shows that the soy bean furnished larger quantities both of dry matter and of nitrogen than either of the varieties of cow peas. It gave practically three-fourths more dry matter, and more than double the nitrogen, furnished by the better of the two varieties of cow pea. It appears impossible to doubt that the manurial value of the soy bean must have been far greater than that of either of the varieties of cow pea. The Kansas Experiment Station reports that the soy bean is capable of resisting injury from drouth to a remarkable extent. It is not the belief of the author that it will equal the cow pea in this direction; and in this respect, as well as in its ability to make a crop on the lightest and driest of soils, the soy bean may be inferior to the cow pea as a green manure; but, under soil and climatic conditions making it possible to grow good crops of the soy bean, the farmer is advised to select it rather than the cow pea as a green manure crop. For fodder, the variety of soy bean mentioned has at least equal value with the cow pea, being readily eaten by cattle when green. Experiments in the Massachusetts Station indicate that the manurial value of the stubble of the bean is not very great, so that the use of this plant for soil improvement and fodder combined seems unlikely to be attended with favorable results. If grown for soil improvement the entire crop should be turned in. The Medium Green soy bean ripens in the latitude of central Massachusetts and farmers can easily produce their own seed. Both the crops under consideration are best grown in drills (528, *d*).

445. *Conditions must be right or green manuring may not prove especially beneficial* — Few of the more important benefits which it is possible to secure by green manuring will be realized unless certain essential conditions exist. What many of these are must have been made clear in the preceding paragraphs, but especial attention will be called to the following points: —

(*a*) *Nitrogen conservation* — It is useless to practice green manuring for the purpose of saving nitrogen unless there is something to save and a probability of loss. On very light and poor soils, nitrogen conservation may be of practically no importance because after a crop has been grown there may not be nitrogen enough there to make loss probable. The crops

grown chiefly for the purpose of saving nitrates, such as white mustard and rape, may prove exceedingly useful in soils fairly rich in organic nitrogen, while on poor soils they may do little good. On the lighter soils there is nothing to save. The writer has seen experiments with grain crops following a crop of white mustard grown as a green manure on both fairly rich and very poor soils. The grain following the mustard on the rich soil was far better than where no mustard had been grown, but on the poor soil there was no visible difference. In order that green manuring for the purpose of nitrate saving may be expedient, there must exist, moreover, a probability that without green manuring the nitrates will be lost. Such probability does exist in the case of all soils containing a considerable store of nitrogen which are of an open, porous character and with open subsoils; but, provided the soil is underlain by hardpan or compact clays, there may be extremely little probability of any loss of nitrates through leaching, and under such circumstances the introduction of a crop with the sole object of nitrogen conservation is unlikely to be profitable. For the purpose of nitrogen conservation, then, such hardy crops as mustard and rape, which have no ability to gather nitrogen, will prove most surely and largely useful on soils rich in nitrogen, coarse and open in texture, and with open subsoil.

(*b*) *Nitrogen gathering* — The increase in the store of nitrogen in the soil, as must have been made clear, is the chief benefit usually aimed at in green manuring. It is exceedingly important to understand the conditions under which such increase may be expected. It will be understood that the crop must be a legume. The opinion appears to be not uncommonly held that if a legume is grown an increase in the stock of soil nitrogen is certain to follow. This is by no means always the case. The legume must be forced to take its nitrogen from the air. If it finds it in the soil it will, like crops of other families, take it from the soil,— it will not go to the air for it. The first essential, then, is that the legume shall be grown on soil which contains only a limited stock of nitrogen in available form. The conditions essential to securing this result have been carefully explained in paragraph 133, *b*. The more important of them may be briefly restated

here : A soil well drained and aerated, containing no free acid, abundantly supplied with the mineral elements of food (phosphoric acid, potash, and lime) ; a soil with a small supply of nitrogen in available forms, the presence of bacteria of the species needed by the legume, and that the legume be allowed to become practically mature.

In the paragraph above referred to, it is pointed out that with the seed of a new legume we usually procure a limited supply of bacteria of the right sort adhering to the seed in the shape of dust. This is not always the case. Experimenters sometimes find that a new legume produces absolutely no nodules. Such being the case, they must be procured in order that the use of the legume as a green manure may prove beneficial. It is stated in the paragraph above referred to that they may be procured either in soil coming from a locality where the legume has long been successfully grown or by the purchase of a culture — the "farmer's yeast cake." Cultures are now offered by some American manufacturers and seedsmen and the cost is relatively low. It is sometimes preferable to procure soil from a suitable locality. If, however, the distance which the soil must be transported is great it is cheaper to use a culture. In ordering, the writer should specify the crop for which a culture is required and the acreage of land on which it is to be used. Directions for use accompany each package. If it is desired to use soil, it is best to have it taken from a field in the soil of which the nodules have been abundant the previous year; and, of course, on the crop for which the soil is to be used. It is impossible to be definite as to the quantity required, as the richness of the soil in the bacteria is doubtless subject to much variation. Experiments, in which from 300 to 500 pounds of soil per acre have been used, have been followed by satisfactory results. This soil, for crops so planted, should be used in drills. It should be scattered broadcast and worked in with a harrow in the case of other crops; in both cases much as a fertilizer would be applied. It should not be exposed to bright sunlight. Such earth, indeed, acts as a fertilizer, giving the crop the ability to gather

nitrogen from the air. Particular attention is called to the fact that the benefits from green manuring with a new legume, even in those cases where the proper bacteria come with the seed, may at first be comparatively small because the supply of bacteria is deficient. This being the case, the crop will at first produce but few nodules on its roots, which means that it cannot take much nitrogen from the air. In such cases it is best to cultivate the crop for a number of successive years upon the same field, under which circumstances the bacteria multiply rapidly. As soon as it is found that the roots show abundant nodules, then the legume may be cultivated on other fields and a little soil from the first used as a means of inoculating the new field. In one experiment at the Massachusetts Station, only about one-tenth of the sweet clover plants grown on a given field developed nodules on their roots the first year. These few plants attained five or six times the size of those without nodules. The crop was harvested, the ground thoroughly worked, and the same crop sown again. The second year about half the plants from the very start developed nodules and made vigorous growth. Before the end of the season all had evidently become capable of making use of atmospheric nitrogen. This crop was harvested, the soil worked, and for a third time sweet clover was sown. All the plants from the very start showed the deep green color and made the vigorous growth characteristic of legumes when making use of atmospheric nitrogen. The result was a magnificent growth from 6½ to 7 feet in height and about five times greater than the yield the first year, — a difference which must have been due to the increase in the number of nodular bacteria. The writer has made similar observations upon winter vetch, and other observers and practical farmers have had similar experiences.

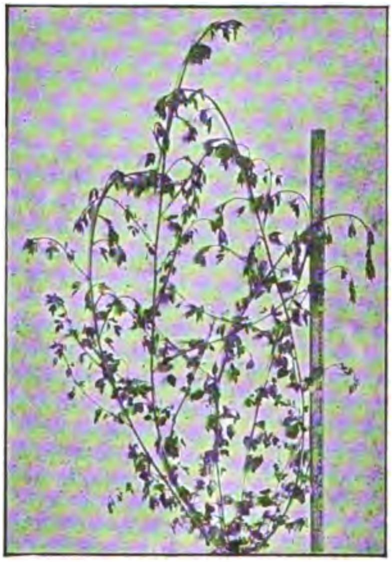


FIG. 83. SWEET CLOVER.

That the turning under of a crop of legumes grown on soil rich in nitrogen may not be followed by an improvement, while great improvement may be the result if the legumes are grown and turned under on a soil poor in nitrogen, has been strikingly shown by numerous experiments. Kuehn, one of the most noted of German experimenters, once turned in a mixed growth of peas, vetches, and lupines, grown upon a soil rich in nitrogen, which amounted to about 4½ tons to the acre. The green material turned under contained 50 pounds of nitrogen, but the following year barley grown on this field gave no larger yield than on an adjoining plot which had not been green manured. The explanation is that in this case the legumes, finding it there in available form, took from the soil the nitrogen they needed. A similar experiment by the same investigator on a poor, sandy loam showed that the legumes turned under increased the grain to the same extent as did the application of 175 pounds of nitrate of soda on an adjoining acre. On the sandy loam, poor in nitrogen, the legumes had been forced to draw upon the air and so the soil was enriched, while on the richer soil this was not the case.

446. *Plowing in green crops* — It is a common practice to turn under crops grown as green manures as soon as their growth is completed, but, as has been indicated, where winter protection from wind or washing is especially needed, it may be preferable to leave the crop on the surface until the following spring. There can be no considerable loss in manurial value as the result of this practice, because the crop will not have decayed during the winter to a sufficient extent to have lost any considerable proportion of its valuable manurial constituents. In deciding upon the precise time of turning under a green crop, the needs of the crop which is to follow must be considered. It is usually best that the green manure be turned under some few weeks before the following crop is to be put in. The presence of a large amount of entirely undecayed vegetable material a few inches below the surface is unfavorable to the germination and early growth of a following crop. It is better that time should be allowed for the vegetable matter turned in to in part decay. A large amount of undecayed vegetable matter near the surface is likely to render the surface soil too dry ; moreover, the

following crop will more certainly utilize the plant food contained in the green manure if the latter be partially decayed before the next crop is planted. If this is not the case, the constituents of the green manure may not become available in season to help the following crop. In a majority of instances it seems best to turn a green crop under. If it is tall, it requires great care to do this well. A plow turning a large furrow slice is best suited to the work, a rolling coulter is desirable, and in case the growth is very high a chain fastened to the middle of the evener or whippletree, and just long enough so that the end will come back to a point about opposite the mold-board, may be used with advantage. The end of this chain drags in the open furrow and, as a result of its use, the standing crop is divided and bent down, so that it is covered far better than would otherwise be the case. If a crop whose growth was completed the previous fall stands through the winter, its stems and leaves become dry and brittle before spring ; and in such cases it is best to go over the field with a disc harrow, cutting up the stems and working the material somewhat into the soil before attempting to plow.

LXII — FARM CROPS.

447. It will be the effort under this general subject to make a clear statement of the general principles on which success in the production of the various crops of the farm and garden depend, without going too largely into details. The details and practical management of the various crops must vary to a considerable extent, as local and individual conditions vary. Principles, in the sense in which the word is here used, are truths of universal application. The number of crops to be considered is very large and, in order to bring the statement of principles within a reasonable space, it will be necessary to consider the crops under different groups or classes ; and the effort will be made to put into each of these groups crops whose management in a number of important particulars is the same, so that one statement of principles will answer for all. All the crops which we are to consider may, in the first place, be put into three great groups, which are designated respectively, annuals, biennials, and perennials. An annual crop is one which completes its growth in a single year. Two subdivisions are

recognized among annuals, viz., winter annuals, and summer annuals. Winter annuals are crops which, like winter wheat and winter rye, are sown in the autumn, live through the winter, and perfect seed the following summer. Summer annuals are crops which, like corn or millet, are sown in the spring and complete their growth during the ensuing season. Besides the annuals of the two kinds which have just been defined, we must recognize in agriculture a third class of plants which, although not truly annuals, are cultivated as such. Among such crops may be named horse-radish and Jerusalem artichoke, both of which are truly perennials.

A biennial crop is one which requires two seasons to perfect its growth. During the first season, the plant develops either a thick, fleshy root, a head, or a bulb which is abundantly stored with nutriment for the production of seed in the second year. Examples of biennials are carrot, beet, cabbage.

Perennial crops are those which live on for a considerable number of years: some almost indefinitely, like some of the grasses; others for comparatively few years, like the common red clover.

To consider the various crops in the groups which have just been defined would not best serve the objects in view, because each of these classes, based upon the length of the life of the plant, would include crops used for very different purposes and requiring very different treatment. For agricultural purposes, it is best to group the crops in classes based in considerable measure upon the use to which the crop is put, or the special part for which it is cultivated. Nevertheless, a knowledge of whether a given crop is annual, biennial, or perennial is not without importance, as the methods of culture and manuring must be to a considerable extent affected by the length of time the crop will occupy the ground. Many of the crops which are to be considered are put to more than one use. Such crops will be named in more than one group, but principles and methods to be followed in their production will in such cases be stated but once, and in each case under that group for which the crop appears to be most important.

448. *Classification.*

CLASS I. FORAGE CROPS.

Sub-Class I. Crops suited for mowings and pastures.
- Group 1. Perennial grasses.
- Group 2. Perennial clovers and alfalfa.

Sub-Class II. Plants suited for annual hay crops, soiling, folding, or ensilage.
- Group 3. Small grains.
- Group 4. Millets.
- Group 5. Indian corn and teosinte.
- Group 6. Sorghum and sorghum-like crops.
- Group 7. Legumes.
- Group 8. Miscellaneous crops.

CLASS II. FIELD CROPS.

Sub-Class III. Crops cultivated for their seeds.
- Group 9. Cereal grains.
  - Wheat,
  - Rye,
  - Oats,
  - Barley,
  - Indian corn.
  - Kaffir corn,
  - Millet,
  - Buckwheat.
- Group 10. Legumes,
  - Peas,
  - Beans.

Sub-Class IV. Crops cultivated for underground parts
- Group 11. Root crops.
  - English turnips,
  - Swedish turnips,
  - Mangel-wurzels,
  - Sugar-beets,
  - Carrots,
  - Parsnips.
- Group 12. Tubers.
  - Potatoes,
  - Sweet potatoes,
  - Jerusalem artichokes.
- Group 13. Bulbs.
  - Onions.

Sub-Class V. Miscellaneous.
- Cabbages,
- Squashes and pumpkins,
- Tobacco,
- Broom corn,
- Hops

LXIII — CROP ROTATION.

449. *What rotation is and its objects* — The term crop rotation is used to designate the system whereby different crops are made to succeed each other in a certain regular or definite order. A rotation is completed when the last one of the crops which are included in it has been harvested. The number of years that the rotation lasts may vary widely. It is designated by prefixing the figure to the word course. A four-course rotation is one including four crops and lasting four years. The object in view in crop rotation is to secure a larger aggregate product from a soil than would be secured should a proper system of arrangement of crops be neglected. It was formerly thought that the roots of our various crops each excreted certain substances harmful to that crop, but harmless or at any rate less harmful to other crops. It was believed that as a result of this root excretion the soil was gradually poisoned, as it were, for a crop continually grown, and that therefore a change was necessary. It is now well understood that this theory is incorrect. Roots do not excrete substances necessarily harmful. We are now able to give numerous other and important reasons to explain the well-known benefits which follow a proper system of rotation.

450. *Reasons why crop rotation is beneficial.*

(*a*) *Food requirements* — To some extent the different crops consume the various elements in different proportions. They also have varying capacity to extract the different food elements from one and the same soil: one crop being able to obtain, for example, a sufficiency of phosphoric acid and potash in a soil where another, which may require no more of these elements, is unable to extract the quantity it needs. Some of our most important crops have been classified in accordance with their food requirements in paragraph 448. It is evidently an advantage, after producing on a soil a crop consuming a large proportion of one element, to follow with another whose demand upon the soil will be different. It is in this connection that one of the chief advantages of rotation is found.

(*b*) *The depth of the root system* — Our crops vary widely in respect to the depth to which they send their feeding roots. It is the object of the

farmer to draw upon the soil for the food which his crops need as largely as possible. Clearly, then, a rotation should include deep rooting as well as shallow rooting crops. The former will take from the soil food the latter cannot reach, and thus the farmer more perfectly utilizes the resources which nature places at his disposal. Among the more important deep feeding crops may be mentioned all the root crops, cabbages, clovers, alfalfa, and hops. Among rather shallow feeding crops may be included most of the grasses, cereal grains, Indian corn, all the melons, squashes, cucumbers, onions, and strawberries. Beans and peas, potatoes, and tobacco send their roots to medium depth.

(*c*) *All crops belong to one of two classes, nitrogen gatherers or nitrogen conservers* — Under green manuring (429), the important distinction which exists between different crops in respect to the sources of the nitrogen they require has been pointed out. It will be remembered that all of our common crops, except the legumes, must take the nitrogen they need from the soil, while the legumes can draw upon the air. It will be remembered that when the legume is harvested it leaves the soil richer in nitrogen than before its growth, if it has been produced under the right conditions; a considerable surplus of nitrogen remaining in the stubble and roots, after the decay of which this nitrogen becomes available to the following crop. It will be remembered that nitrogen is the most costly of the elements of plant food. It must be clear, therefore, that an important economy may be effected in crop production if in every rotation at least one nitrogen-gathering crop can be included.

(*d*) *Liability to disease, insect injury, and weeds.*

1st. Disease. Most of the diseases which affect our field and garden crops are due primarily to the growth upon or in some part of the plant of a parasitic fungus. The parasitic fungi are of microscopic dimensions but none the less real. They are propagated in most cases by means of spores, in accordance with the same general rules as those which govern the propagation of the larger plants of the fields and woods. Each disease from which our various crops suffer is produced by a specific fungus. Potato rot by one fungus, potato scab by another, corn smut by another, and so

on throughout the entire list of fungoid diseases. The fungus which can grow in or upon one plant, causing it to become diseased, is usually powerless for injury on other plants, though in some cases it may affect a few very closely related plants. It seldom happens that a crop is produced in which there are not some diseased plants. The amount of injury may be so slight as not to attract attention, but the fungi which cause plant diseases are most of them capable of multiplying with extraordinary rapidity, and thus, since we practically always have some disease, if we continue to grow the same crop for a number of successive years on a given soil, the amount of disease tends to increase, and often at a very rapid rate. There is, it is true, a wide difference between different diseases in respect to the rapidity with which they increase. Some increase so slowly that it is safe to cultivate a crop for many years in succession, while in other cases disease tends to increase so rapidly that to cultivate a crop for even two successive years upon the same ground is unwise. Among diseases which do not appear to increase very rapidly, may be mentioned corn smut, ergot in rye, onion smut; and among diseases which increase very rapidly may be named potato rot, potato scab, and club root in cabbages, turnips, etc. The advantage of rotation, as a means of lessening the ravages of plant diseases, must be evident.

2d. Insects. The principles underlying the advantages connected with insect injury which may be derived from rotation are identical with those which have just been stated under disease. To a considerable extent, each crop has its own insect enemies, and these, in many cases, are entirely harmless to other crops. It will be understood that there are wide differences between insects: some have a large number of food plants, while many others prey only upon one or a few closely related plants. It must not be expected that by rotation we shall succeed in entirely escaping the ravages of insects, because many species at some stage in their life travel freely from field to field. There are many, however, which are quite sluggish in their movements and by rotation we, to some extent, lessen the probability of injury.

3d. Weeds. The reasons connected with the growth of weeds which

oftentimes render rotation an advantage are in part the same as those considered under the last two heads, for, to some extent, each crop has its own specially injurious weeds. There is, however, another important consideration. With certain crops, there is much difficulty in keeping down the growth of weeds. Fields and gardens tend to become increasingly stocked with weeds of certain kinds. This is especially true of most of the grains as they are grown in this country. Other crops which receive more careful culture, or which come up quickly, grow rapidly from the start, and quickly shade the ground, are much more favorable to the keeping down of weeds; and, in order that the spread of these pests may be lessened as far as possible, it is expedient to include at least one crop of this character in every rotation.

451. *Planning the rotation* — The particular arrangement of crops in rotation which will prove best must vary with individual conditions. A system which meets all the scientific requirements may prove ill adapted to the needs of a particular farmer or gardener. Crops which can be profitably produced are determined by local conditions of soil and market, and these vary widely. The planning of a rotation must, therefore, be largely left to the individual. Each for himself should aim to adopt a system satisfying at the same time the scientific principles which have been pointed out, and the economic requirements of the individual case. A few examples of systems of rotation, which have been found widely useful, will be given largely as a means of illustrating the application of the principles which have been laid down.

LXIV — SYSTEMS OF ROTATION.

452. *The Norfolk system* — The Norfolk system of rotation is in extensive use in England and, with slight modifications, in many other countries. It takes its name from the county in England where it was first extensively followed. This is a four-course system, and the crops and the order in which they are placed are as follows: turnips, barley, clover, wheat, each for one year. The turnip may be either the English or the Swedish. This is a rank feeding crop and to it a large part of the manure made upon the

farm is applied. It is planted late in the season so that the ground can be cleansed from weeds before the seed is put in ; it then grows rapidly, shades the ground, and keeps down weeds. It is the cleansing crop in the rotation. It is a deep feeding crop and is especially benefited by potash. This is followed by barley, a more shallow feeding crop, a grain which does best on the old fertility of the soil. It is one of the crops especially requiring available nitrogen. The clover which follows the barley is a deep feeding crop, a nitrogen gatherer, especially benefited by potash. This leaves the soil in good condition for wheat, a nitrogen consuming crop. The principles which underlie rotation, as will be seen, are therefore very perfectly met by this system. No one of these crops is likely to be affected by the diseases or insect enemies which attack the preceding crop.

453. *Modifications of the Norfolk system.*

(*a*) On farms where a large amount of live stock is kept, it is desirable to produce more forage than the Norfolk system would give, since under that system only one-fourth of the land would be kept yearly in clover. On such farms, therefore, the following rotation is often followed : turnips, barley, mixed grass and clover, mixed grass and clover, mixed grass and clover, wheat. This makes a six-course rotation and one-half the land, as will be seen, would yearly produce hay.

(*b*) In districts where sugar beets and cereal grains are largely grown, and where the quantity of live stock kept is not very large, the rotation is often as follows : sugar beets, barley, clover, wheat. This, as will be seen, is but very slightly different from the Norfolk rotation.

(*c*) Other possible modifications of the Norfolk system, which may render it better adapted to special conditions, will readily suggest themselves to any intelligent farmer. A few of them only will be named : mangel-wurzels may be grown instead of turnips, if desired ; oats might be substituted for the barley ; or rye for wheat. Modified in any of these ways, the rotation would still satisfy all the scientific requirements.

454. *Rotations followed in corn growing states* — In the chief corn growing states of the prairie regions, the following rotations are common :

grass and clover for three years, corn two years, wheat or oats one year. With either of these grains would be sown mixed grass and clover seeds. This makes a six-course rotation and one-half the land would each year produce a hay crop. Under this system of rotation, most of the manure of home production is applied to the grass. In localities where the soil is especially rich, the corn is often grown more than two years, and on the other hand if it is poorer than the average or ill suited to corn, that crop may be grown for but one year.

Another rotation followed in many parts of the West is as follows : corn, oats, wheat, grass and clover, the seeds of the latter being sown in the wheat. In this rotation the manure is applied to the oat stubble in preparation for wheat.

455. *Terry's rotation* — Mr. T. B. Terry, the skillful farmer and prominent agricultural writer of Ohio, practices the following three-course rotation: clover, potatoes, winter wheat. Under this system, he finds that the productive capacity of his farm has been greatly increased. The frequent introduction of the clover crop is, in Terry's opinion, the chief reason for this improvement.

456. *A dairy farm rotation* — A rotation which is common in many parts of Massachusetts where dairying is prominent, and where the potato is usually a profitable money crop, is as follows : potatoes, corn for two years (the second year for ensilage), grass and clover three years. Under this system one-half the ground is annually in grass. The potatoes are raised chiefly on fertilizer. Homemade manures are applied to the corn crop, together with some material furnishing potash. The grass and clover seeds are sown in the standing corn, at the time of the last cultivation, and the third year the grass is often profitably top-dressed with nitrate of soda. This system is susceptible of several slight modifications to fit it better for local conditions. Corn as a grain crop may not be required or may be unprofitable, in which case corn may occur in the rotation but one year. Or it may be that three years in grass and clover will give too large a proportion of hay ground, in which case these crops may occupy the land two years instead of three.

457. *Rhode Island rotations* — The Rhode Island Station reports favorably upon the following rotations : —

(*a*) Potatoes, winter rye, clover.

(*b*) Corn, potatoes, rye, clover.

(*c*) Corn, potatoes, rye, grass and clover for two years.

These rotations are stated to be adapted to light and exhausted soils.

LXV — METHODS OF PROPAGATING PLANTS.

458. *Different methods named* — All cultivated plants are propagated in one of two entirely distinct methods, viz., from seeds, or from buds. In the case of most of the ordinary crops of the farm, propagation from seed is the rule. In the case of very many fruits and a few farm crops, the variety is propagated and perpetuated by such a course of management as will provide a bud with roots, and enable it to develop into an independent plant. Propagation from seeds, provided the seeds be of good quality, produces new plants of the same kind as the plant which bore the seed, in the case of most of our farm crops. A given variety of corn, we produce from seed of the same variety. The same is true of varieties of wheat and most garden vegetables. It is in the case of fruits, especially the tree and bush fruits, that some kind of bud propagation is necessary, for the reason that if the seed be planted it does not produce an individual that will bear fruit of the same kind as that from which the seed was taken. A Baldwin apple seed does not necessarily produce Baldwin apple trees, indeed, it seldom or never would produce Baldwin apple trees. If, then, the grower would secure Baldwin apples, he must adopt some method of bud propagation. In the case of some of the ordinary crops of the farm, bud propagation is necessary in order to perpetuate a variety, or it may be because it is a better way to secure a paying crop. This is true of potatoes. A potato plant produces fruit and seeds under normal conditions, although many of our improved and highly cultivated potatoes do not bear much fruit. They blossom but do not mature the so-called seed balls. It would be impossible, however, to perpetuate any variety of potatoes by planting the seed

from seed balls produced on that variety. The new plants would not be true to the parent type. To propagate a given variety of potatoes, we plant the tuber, and the tuber is a kind of stem and the eyes on the potato are buds; and when the tuber is planted roots are formed and these buds grow into shoots, and new tubers are produced which are always like the parent form. The sweet potato is propagated by planting pieces of the fleshy root. In both these cases buds, which grow into shoots, and roots are produced, thus making new individuals which are like the parent form. In all these cases the method of propagation followed is not alone the only method whereby the variety can be propagated; it would be the best method, even could the true variety be produced from the seed, for the reason that the plant produced from the tuber or thick root is more vigorous and fruitful than the smaller plant which might be produced from the seed. With the great majority of the crops of the farm and garden, propagation by seeds as has been indicated is the rule, and since the tree and bush fruits are not to be considered in this work, we shall have nothing further to say concerning bud propagation. The farmer speaks of potatoes which he proposes to plant as "seed potatoes," but the store of nourishment for the young plant in a tuber like the common potato, or in the thick, fleshy root like the sweet potato, is very much greater than it is in a single seed. Because of this difference, it may be somewhat less necessary to bring the soil into perfect tilth for these crops than in the case of crops propagated from seed.

LXVI — SEED PROPAGATION.

459. *What a seed is* — Every seed contains a little plant or the rudiments of a plant already formed. The leaves, a bud, a part of the stem, and the point from which the root will grow can all be recognized. Besides the little plant, the seed has a store of food designed to help the plant to begin its growth. Sometimes the leaves of the little plant which is found in the seed are made very thick and fleshy and contain the food with which the plant will begin its growth; sometimes the little plant or embryo, as the botanists call it, is made very small and the food is packed away in the

tissues which surround the embryo. The food stored away in the seed is in many cases largely starch. Besides starch, many seeds contain oil or fat and some form of proteids. It is chiefly this store of food, which the plant packs away in the seed to help it begin its growth the next year, which renders the seeds of cultivated plants valuable to man. Thus it is the starch and the proteids chiefly of wheat, rye, and corn which make these grains suitable for food for man and animals. It is the proteids stored away in beans and peas which make them valuable foods, while all these seeds contain some oil or fat which, also, is valuable for food. Some seeds contain so large an amount of fat or oil as to make its extraction profitable. Cottonseed is an example; linseed and rape seed are other examples. We do not need, at this point, however, to consider the food value of seeds, but simply the relation of the food materials which are stored away in the seed to the growth of the new plant which comes from it. In the vegetable economy, the food packed into the seed is put there solely with reference to the growth of the new plant.

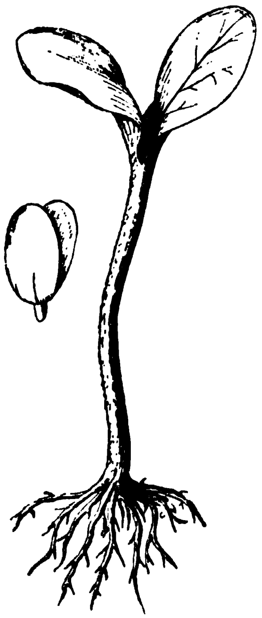


FIG. 84. SQUASH SEED AND YOUNG PLANT. The food for the young plant is stored in the thick seed leaves.

Besides the parts of the seed which have been named, there are coverings — the skin or husk, or it may be both — and in not a few cases the seed is provided with some special device which is favorable to its distribution. Thus the seeds of the carrot, for instance, are covered with little spines whereby the seed attaches itself to animals who may carry it long distances. Other seeds are provided with special woolly or hairy growths or with wings which increase the probability that the seed may be carried considerable distances by means of the wind. In the case of plants growing wild, these contrivances, which are only a few among many that might be mentioned which are favorable to the distribution of seeds, are highly important; but in the case of the seeds used on the farm and garden, man

attends to the distribution, and such special organs are rather a hindrance than otherwise because they make it more difficult to plant the seed evenly, whether by machine or hand. In the preparation of seeds for market, such special contrivances are therefore removed if possible.

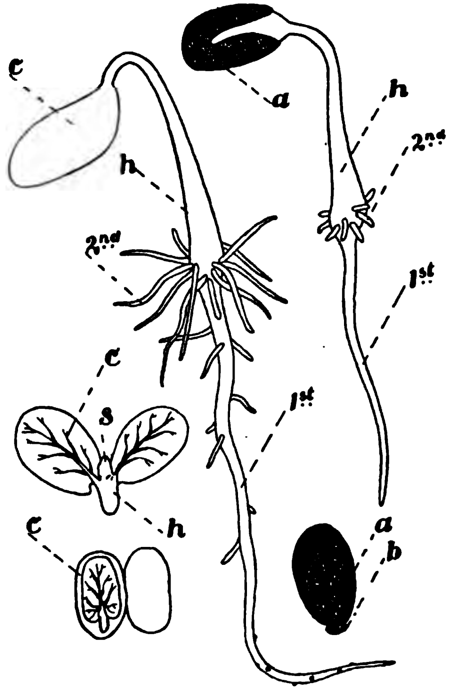


FIG. 85. CASTOR BEAN: *a*, seed coat; *c*, seed leaf surrounded by store of nutriment in lowest figure; *s*, bud; 1st, tap root; 2d, branch roots; *h*, stem.

460. *Importance of good seed* — There is no single factor connected with the production of crops of greater importance than a start with *good* seed. Like produces like is equally as true in its application to the vegetable world as in the animal world. One cannot expect a good and thoroughly satisfactory crop unless one has good seed with which to start. The following statement, based upon the experience of the author while in Japan, illustrates in a striking way the importance of good seed, and it is a statement which might be paralleled by thousands, founded upon the experience of farmers and gardeners in all parts of the world. Upon the College Farm of which the author had charge, oats were yearly raised in large quantities. The seed in use at the time he assumed the management was of a slender, pointed variety of white oats, weighing 28 pounds to the measured bushel, and giving an annual yield of about 40 bushels to the acre. Seed of a very thick, short, and plump white oat, which weighed 46 pounds to the measured bushel, was procured from England. This seed, on precisely the same kind of soil, and with similar manuring and management in every respect, gave a crop at the rate of about 70 bushels to the acre, of grain

that weighed about 36 pounds to the measured bushel. Here was an extraordinary gain, undoubtedly due solely to the better quality of the seed used. On another occasion the writer, having imported to Japan from America carrot seed, supposed to be sufficient for the desired area, found the quantity of seed not quite large enough to finish sowing the field. Accordingly the balance of the field was planted with an unimproved Japanese variety. The crop on the part of the field planted with the latter produced an enormous proportion of roots that ran to seed the first year, the root itself being slender, tough, and worthless. The part of the field planted with American seed gave a yield of smooth, fine-shaped roots, at the rate of more than 20 tons to the acre. It is important to recognize that seed must be adapted to the local conditions existing where it is to be planted. A variety which is excellent in one locality may prove practically valueless in another. The writer has imported, both while in Japan and since returning to America from that country, a number of varieties of wheat from England. The samples of English seed were very perfect, with large, plump, bright kernels, and very uniform in size and shape, showing that the varieties had been carefully bred and selected. Such seed both in Japan and in the United States proved worthless. It came from the most reliable of English seedsmen and was without doubt splendid seed for England, but it was not suited to the local conditions existing in either of the countries to which it was imported. The writer has had a similar experience with Scotch potatoes which were splendid in quality, large, well-shaped, and mealy, but when planted in Massachusetts such potatoes have proved almost absolutely worthless. It is necessary, then, as must be clearly understood from the examples which have been given, before undertaking the extensive growth of a new variety, to have made certain that it is suited to the locality in which it is to be introduced.

461. *Changing seed* — In the case of many farm and garden crops it is best, every few years at least and in some cases every year, to plant seed produced in another locality rather than that of one's own production. In every locality there must exist certain conditions which are unfavorable, others which are favorable, to the best development of any given variety,

and in most cases the usual result of continuing to use one's own seed is that the unfavorable influence causes a gradual deterioration in certain respects. This tendency to deterioration may be overcome by taking seed from another locality, where also there may be a tendency to a loss in some direction, but where it is likely that the tendency will be in a different direction from that existing at home. There would seem to be an analogy here between the vegetable world and the animal world. In certain sections of the country, as for example in New England, there is a tendency to tuberculosis and rheumatism in the human family. Continued intermarriages between individuals of that locality may result in a greatly increased tendency toward these diseases. In another section of the country, let us take for example the elevated plateau between the Missouri river and the Rocky mountains, lung diseases are very uncommon, while diseases of the heart and nervous system are common. Marriages between individuals from these two sections are likely to result in more healthy offspring than are marriages in either section between individuals native to that section. To come back to the vegetable world: many of the smaller grains grown in New England tend to produce very long jointed, slender straw, liable to lodge. By continued use of one's own seed this tendency goes on increasing. If seed can be taken from a region farther north or where lime is more abundant in the soil, the plant is likely to be shorter jointed, stouter, and less liable to lodge; and such seed will retain these characteristics in part at least for a time, and will therefore give better results than seed of one's own production. It is impossible to go into much detail upon this point, and much no doubt remains to be learned concerning the desirability and the effect of changes from one locality to another. For practical purposes, the matter may be summed up by saying that, in the case of very many of our crops, the use of seed grown farther to the north is likely to be followed by heavier yields and an earlier crop, the latter being in many cases a most important consideration. Thus, for example, in many parts of the Northeastern states where the potato is grown as a money crop it proves most profitable if early. The seed which comes from northern Maine may be counted upon to give a crop earlier by a number of days and also, in the

writer's experience, a heavier yield, the difference in yield itself being more than sufficient to repay the extra cost of obtaining the Maine seed. So, too, in the case of many grains: seed grown somewhat farther north gives much more satisfactory results both in yield and in earliness of maturity. It is important to keep in mind that a very violent change is not as a rule desirable. As is clear from the examples we have cited, the violent change from Scotland and England was unfavorable in the case of wheat and potatoes. It seems as a rule best to take the new seed from a locality not very far to the north of one's own. No exact distance can be stated but it is believed that some two or three degrees of latitude may usually prove sufficient. One more point: when a change is to be made, it seems best to take seed from a locality where the conditions are somewhat less favorable than one's own, rather than from a locality where they are more favorable. When a change of the first kind is made, the plant responds to the improved conditions and good returns are the consequence; but if a violent change from good conditions to a locality with poorer conditions is made, the influence upon the crop is highly unfavorable, and returns may be even less satisfactory than they would be with one's own seed.

462. *The characteristics of good seed.*

(*a*) *The seed must be genuine, i. e., it must be of the kind or variety which the farmer wants*—The intelligent farmer or gardener learns what variety suits his local conditions, what variety is adapted to his soil, to his climate, and what variety suits the markets in which it must be sold. It is usually a great loss to such farmers if, after purchasing seed, it is found that the variety is different from what it was supposed to be. Though it may be a good variety in some places, possibly even better than the one the farmer asks for, still it may cause a loss to the farmer to have the substitution made. The first essential, then, in the purchase of seed is that it be true to the type. In order that it may be true to the type, it is not enough that dishonest intention be absent,—the seed must be grown under suitable conditions, so as to make sure that it will have the qualities expected. It must have come from good stock and stock which has a good ancestry for as many generations as possible, and it must in many cases have been grown

at a distance from other varieties of the same species, for otherwise the seed may be a cross and not a pure-bred product (472).

(*b*) *The seed should be free from foreign material of any kind*—It must not be mixed with dirt or with weed seeds. A mixture with dirt of any kind often interferes with the regular distribution of the seed in planting, and of course the payment for dirt is a direct loss. Much worse, however, than a mixture with any such amount of dirt as is usually found in samples of seed, is the presence of the seeds of weeds. This is most common with grass and clover seeds, which are often more or less mixed with seeds of weeds such as sorrel, dock, and many others. It is common also with some of the small grains, which are mixed with the seed of black mustard, wild turnip, and possibly others. The injury which follows planting weeds with a crop is too evident to need explanation. All seeds, then, should be freed as perfectly as possible from mixture with weed seeds. It will pay the intelligent farmer to gather a few heads or pods from some of the most injurious weeds of his section when ripe, to save the seed, if he is not already familiar with its appearance, in little vials or envelopes for convenient examination. Then, before purchasing grass and clover seeds in large quantities, he should take samples, spread them on sheets of white paper, and carefully look them over to determine whether they contain the seeds of such weeds as he knows to be injurious. In case of doubt, samples of weed seed found mixed with purchased seeds should be sent to experiment stations for identification. If this precaution should be taken, the introduction of new and possibly pernicious weeds might often be prevented. Seeds of some kinds, moreover, sometimes contain a good many diseased individuals, or the spores from which diseases take their origin. To determine whether or not this is the case, would be difficult for the farmer, as it may require the use of the microscope. It would be well for the experiment stations to examine seeds to determine their quality in this respect.

(*c*) *Weight and specific gravity*—While it may not invariably be true that the seed which weighs most to a given volume, say per quart or bushel, is best, this will usually be found to be the case. It is also usually true that the greater the specific gravity of seed the better. Only seeds

which are well nourished, well stored with food for the young plant, will show the highest volume-weight and specific gravity; and such seed is self-evidently the best because, the food for the young plant being abundant, that plant will make a more vigorous growth.

(*d*) *The seed should be plump* — The skin, with a few exceptions, as in the case of certain wrinkled varieties of peas, sweet corn, and onions, should be well filled, and smooth, the seed thick. Such seed contains most food for the young plant.

(*e*) *Color and lustre* — Good seed is characterized by a bright, clear color appropriate to the species and, as a rule, by a certain amount of lustre. It has a shiny appearance. This characteristic indicates well ripened, well cured seed. Color and lustre are both affected by the manner in which the seed is stored and kept. If put away in large bulk while containing too much moisture, seed may heat and mould and this will give it a dull surface.

(*f*) *The age* — By the age of the seed, we designate the length of time which has elapsed since its harvest. There is much difference among seeds as regards the length of time which they may safely be kept and still have the capacity to germinate; and in the case of all seeds this length of time is affected by the way in which the seed is cured and kept. As a general rule, seeds should be dried only just sufficiently to make it possible to keep them in moderate bulk, and after they have been dried, they should be kept in closed receptacles to avoid further drying. There are exceptions, of course, among which Indian corn is one of the most prominent. It does not seem to be possible to overdry this under ordinary conditions. The fullest exposure of the ears of unshelled corn to the air, almost up to the time of planting, seems to be best. While many seeds will germinate when two or three years old, and a considerable number when much older, it is best as a rule that the seed be not over one year old. In the case of autumn-sown grass and grains, seeds of the same season's harvest are preferable to seed of the previous year, although doubtless most of that of the previous year would grow. In case of spring-sown seeds, the product of the harvest of the previous summer or autumn is generally to be preferred. Doubtless, in

many of the cases where seeds germinate unsatisfactorily, the cause is that it is too old.

(*g*) *Germination* — This name is given to the process whereby a seed, which may have lain dormant for months or years, starts into life and produces a new plant. Rarely is it the case that all the seeds planted will germinate. A certain percentage of failure must be expected because not every seed can be perfect. The higher the percentage of the total number of seeds that germinate the better. The truth of this proposition is self-evident. In some states, seed dealers are required to guarantee that a certain percentage of the seeds offered for sale will germinate, and laws requiring this are the rule in most European countries. It seems desirable that the experiment stations in this country should be more generally enabled to exercise a control over the business of dealing in seeds. It is only reasonable that the dealer should guarantee genuineness, a certain percentage of purity, and a certain percentage of germination. It must be recognized, however, that the latter guaranty must be wisely interpreted. Conditions in the field and garden cannot always be controlled, and they are sometimes highly unfavorable to good germination. Some farmers and gardeners prepare the soil and plant the seeds very carelessly. Under such circumstances, good germination cannot be expected. Methods of testing the germination of seeds have long been carefully studied, both in foreign countries and in the United States, and many good methods are known,—methods which give results fair alike to the dealer and the buyer. The buyer cannot complain if seed, which under good and reliable conditions germinates well, fails to do so under unfavorable conditions. Until experiment stations assume this work, intelligent farmers and gardeners who use large quantities of seed of different kinds are advised to test them for themselves, in order to determine whether they will germinate. The following method is simple and gives reliable results. It is in use in some of the large seed-control experiment stations. Take an ordinary soup plate and fill it almost level with a medium grade of sand, add water until the water begins to stand at the top ; then take a pane of glass, place it over the soup plate, and tip the latter sufficiently to allow any excess of water to drain

away. Hold it in this position until it ceases to drip. Then make the surface of the sand smooth and on it place the seeds to be tested. In the case of most seeds, it is convenient to take about 100, though with some of the larger this might be too large a number for the capacity of a single soup plate. The seeds should be pressed to about one-half their thickness into the sand, but not covered with it. Over this plate, after the seed is in position, place a pane of glass and on the pane of glass place another soup plate, bottom side up. This plate is used in order to protect the seed from the light, which is unfavorable to germination. If sand of suitable quality has been selected, it will be unnecessary to add any more water. The plates can be kept in any ordinary living room, and from time to time the cover plate and glass can be removed and the seeds examined, and the number which germinate counted. In the case of some seeds, the percentage of germination is always low. This is especially true in the case of some grass seeds. It does not seem to be possible to avoid it. In the case of most seeds, germination should reach at least about 70 per cent., and in case of some, such as corn, cereal grains, beans, and peas, it should be considerably greater.

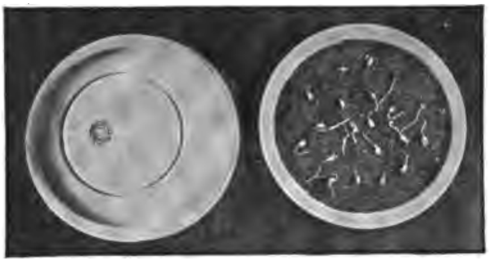


FIG. 86. Simple method of testing seeds on sand: 1, Closed, lower plate with sand, glass, and then plate reversed on top to exclude light. 2, Shows corn about 100 hours after starting. Every kernel except one has sprouted.

LXVII — PLANTING SEEDS.

463. *Preparation of the soil* — The requirements for the germination of seed are a proper degree of moisture, air, and a suitable temperature, and the preparation of the soil must be directed to bringing it into such condition as to furnish these requisites — each to the most favorable degree. Since both water and air are essential, it must be clearly perceived that seed will not grow in a water-logged soil. There it finds water enough but not sufficient air, and it rots. On the other hand, it will not grow in a soil that

is overdry. A soil which is fairly mellow, which contains a little more than one-half of the total amount of water it is capable of holding, and in which a considerable proportion of the interspaces is filled with air, is in the condition most favorable to the germination of seeds. The initial step in the process of germination is the swelling of the seed, which is due to the absorption of water, but, as stated, the seed must not lie in water. It must, however, be in close contact on all its sides with the particles of the soil, in order that it may take from these particles a portion of the capillary water which they hold. Soil, then, in preparation for seed should be thoroughly fined. If lumpy, there is danger that large air spaces between the lumps may lie close to the seed and thus prevent it from obtaining the needed moisture. There is much difference in the amount of care which it may pay to use in the preparation of the soil for different seeds, though, as a rule, farmers are apt to be too careless, rather than otherwise. Still, it is self-evident that less careful preparation will be essential in the case of crops such as potatoes, corn, and beans, than for those where the seed is smaller, the young plantlets more delicate, and the growth at the start more feeble and slow. In the case of the crops just designated, the store of food for the nutriment of the new plant is large, and it may succeed in getting a good start under conditions in which more delicate growths would fail to do so. The utmost care in fining the soil is essential for such crops as onions, carrots, celery, and many others with similar characteristics. There is, further, great individual difference between plants, in respect to the degree of compactness of soil favorable to growth. With some, among which Indian corn is an example, the soil should be very loose and friable. It should, as a rule, be plowed but a short time before the seed is planted. At the other extreme is wheat, which thrives best in a somewhat compact soil. In preparation for this crop, it is best to plow some weeks before the seed is put in, and the later operations in preparation for seeding may well be such as tend to make the lower strata of the soil quite firm and solid. The depth of preparation must vary for the different crops. For sugar beets, the soil must be mellow the full depth to which the beet root extends, in order that it may develop wholly under ground and produce the smooth

root which the sugar maker desires. For Indian corn, on the other hand, it seems unnecessary to work the soil to a very great depth. Notwithstanding the fact that certain crops may thrive with shallow preparatory culture, it is, without doubt, the more frequent fault among farmers to plow and work the soil to insufficient depth rather than the reverse. Though many crops will grow in soils not deeply worked, there are few which will not do better in deep than in shallow soils.

464. *The quantity of seed*— Under the several crops, some detailed statements will usually be given concerning the quantity of seed required per acre. There are, however, a few conditions which have a general application, which must be here stated.

(*a*) The quantity of any seed which it will pay to use may vary with the object for which the crop is to be grown. Cereal grains and corn, when grown for fodder, are more thickly sown than when grown for grain. Sugar beets, when grown for sugar factories, should be more closely planted than when grown for stock, because the sugar manufacturer demands a root of comparatively small size, which experience has shown to be of a better quality than large roots. A sugar beet grown for seed stock, among the celebrated seed growers of Germany and other countries, is still more thickly planted.

(*b*) The quantity of seed required varies with the soil. The poorer the soil, the greater the quantity of seed which should usually be used. Individual plants, on a poor soil, are relatively small, and they do not require as much room as individual plants on a richer soil. Many of the grains stool very abundantly on rich soils, but little on poorer or drier soils. Far less seed, therefore, suffices on those soils which are of such a character as to favor the development of large individual plants.

(*c*) The quantity of seed required may vary with the season when it is planted, with few exceptions. If any crop is planted out of season, whether too early or too late, but especially if planted somewhat too late, more seed is required than if planted in season. Oats should be sown, for example, as early in spring as possible. If sown at that time, the individual plants stool abundantly. From a single root a large number of stems are

produced. A comparatively small quantity of seed suffices. If sown late, the weather being warm, oats stool far less and more seed is required.

(*d*) The quantity of seed required may vary with its quality, especially as regards percentage of germination, and, to some extent no doubt, with variety. Where the percentage of germination is found by trial to be low, or is reported by the seedsman to be low, it is self-evident that the quantity of seed used must be relatively large.

465. *The depth to which seeds should be covered* — The depth to which seeds should be covered varies with the soil and with the season. In soils retentive of moisture, or early in the season, when the amount of moisture in the soil is likely to be large, comparatively shallow covering should be the rule. In proportion as the soil is light, sandy, inclined to be dry or the season hot and dry, the deeper should be the covering. No invariable rule as to depth of any single seed, therefore, can be given, and of course the depth of covering required by different seeds varies widely. It will, however, generally be found that a depth of cover equal to from about three to five times the short diameter of the seed will be suitable.

466. *Compacting the soil after planting* — It has been pointed out that the seed must be planted under conditions which insure close contact between the soil particles and itself. To make this contact as close as possible, many recommend compacting the soil above and about seed which has been planted. In the case of all the lighter soils, soils which are exceedingly mellow and loose at the time of planting, soils which have little capillarity (96), this process is useful. It makes it the more certain that the seed will be able to get the water it needs. In the case of soils with great capillarity, soils which contain a great deal of clay or silt and which incline to form a crust, which become very compact and solid after rains, it is better that the soil about the seed be left as light as possible. Most of the planters used in putting in the ordinary field and garden crops are provided with a roller, and its use is sometimes necessary for covering the seed, but in the case of soils inclined to crust formation it is better that the rolling be omitted or that it be made as light as possible. Whether or not the field which has been sown to one of the cereal grains should be rolled, should be deter-

mined by similar considerations. On all the lighter, drier soils, rolling is quite certain to be beneficial.

LXVIII — THE PLANT.

467. *The parts of the plant* — In order that what follows concerning the different crops may be the better understood, it is essential that a little information should be given concerning the different parts of plants and their functions. Broadly speaking, it may be said that the parts of such plants as man cultivates (mushrooms and a few water plants excepted), are root, stem, bud, leaf, and flower.

FIG. 87. TAP-ROOT, CLOVER.

FIG. 88. FIBROUS ROOT, WHEAT.

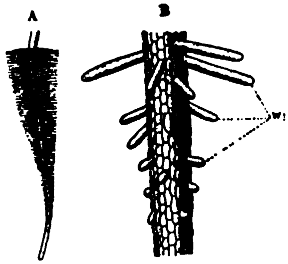


FIG. 89. ROOT HAIRS: *a*, slightly magnified; *b*, much magnified. *Giessenhagen.*

468. *The root* — The root holds the plant in place, and supports and braces it, so that it may stand in spite of the winds which tend to blow it over. The root, moreover, takes from the soil the water and much of the food which the plant needs. The roots of different plants vary widely; some have a long tapering root running straight down into the ground in line with the stem, though in the opposite direction. This is the tap root. The common red clover and alfalfa are examples of plants with well developed tap root. Such roots bear many branches, and these branches may divide again and again. Many plants have no well developed leading or tap root, but produce a large number of roots, all of about equal size and starting

from about the same point. Grasses and grains have roots of this character. We find on all roots which are actively growing, and taking water and food from the soil, a very large number of so-called root hairs. These are excessively slender, sometimes hardly visible to the naked eye. They are found near the tips of the feeding roots, and it is these hairs that are most active in taking water and food from the soil.

Planted thin. Thicker. Very thick.

FIG. 90. SOY BEAN PLANTS, after leaves had fallen; shows effect of thickness of planting.

469. *The stem* — The stem of the plant serves to carry the leaves up into the light. Leaves without good light are unable to discharge their functions. The stem raises them from the ground, and in many cases branches distribute the leaves so that they are favorably placed both with reference to light and air. The stem, moreover, supports the flowers and the fruit. It makes up the framework of that part of the plant which grows above the surface of the ground. When plants are crowded their stems become tall and slender.

470. *The bud* — Buds are of two kinds: those which will develop into flowers and those from which leaves and new shoots will grow. In both cases the bud contains, in miniature, all the parts which will develop from it snugly folded together but only partially developed. It is by the bud, as has been pointed out (458), that the characteristics of an individual plant are most certainly transmitted. It is the leaf bud which is used for this purpose.

FIG. 91. Half of a leaf, which was covered except where letters are; their dark color is due to starch which formed in the light. The word is German for starch. *Giessenhagen.*

471. *The leaf* — It is the function of the leaf to take food from the air and to digest and assimilate that food. In the leaf, when exposed to light, is formed the starch from which, with slight modifications, many of the substances found in plants are formed. The leaf, moreover, is the breathing organ of the plant. It is provided with little openings (stoma), mostly on the lower surface, which communicate with open spaces in its tissues, and through these openings the air enters the plant.

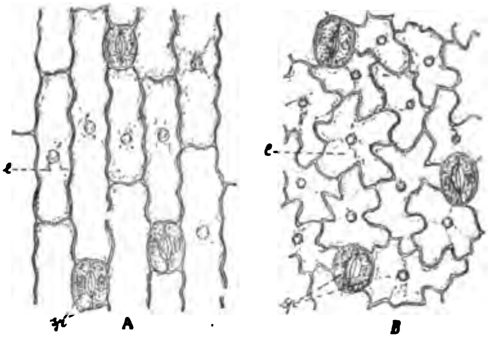


FIG. 92. Breathing pores (stomata) in leaves; much magnified. *Giesenhagen.*

472. *The flower* — The flower contains those organs which are necessary for the production of fruit and seed. In most cases it is provided with parts which protect these organs; and in very many cases flowers have bright colors or attractive odors, or secrete honey, in order that insects may be led to visit them. The absolutely essential parts of the perfect flower are pistil and stamens.

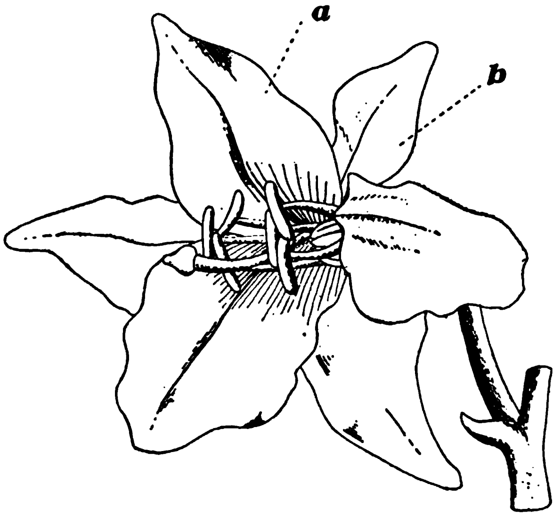


FIG. 93. LILY FLOWER; *a*, petal; *b*, sepal.

(*a*) *The pistil*—The pistil is the female part of the flower. Its essential parts are an ovary, which contains ovules (eggs) which may develop into seeds if fertilized by the male element of the plant, and the stigma, which is so contrived that it is likely to catch and hold the

pollen or male element, which is shed at the time when the ovules are ready to receive it. The surface of the stigma, in many cases, is somewhat adhesive; in other cases, as in the grasses, it is covered with little hair-like bodies, among which the grains of pollen are likely to be caught and held. In the case of many pistils, the stigma may be some distance from the ovary, in which case there may be a stem-like organ connecting the two. This is called a style. In the case of some flowers there is but a single pistil, while others may have two or three or sometimes many.

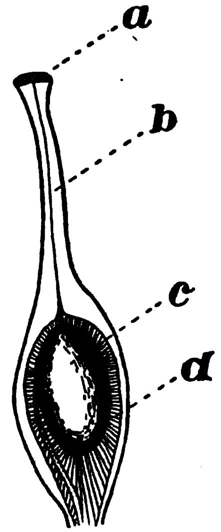


FIG. 94. APRICOT PISTIL: *a*, stigma; *b*, style; *c*, ovule.

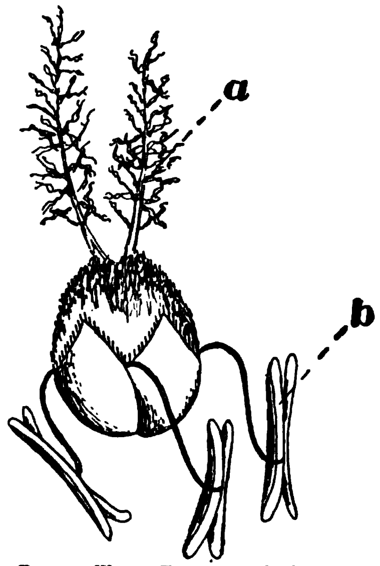


FIG. 95. WHEAT FLOWER: *a*, feathery pistil; *b*, stamen.

(*b*) *Stamens* — The stamen is the male part of the plant. Its essential parts are the filament, which is usually long and slender and is really the stem of the stamen, the anther, and pollen. The filament grows to such a length as is necessary to bring the anther into the most favorable position for the discharge of its final function, which is to shed the pollen. Pollen is the name given to that substance, usually powdery and yellow in color, on whose action the fertilization of the ovules depends. When a grain of pollen falls upon the stigma, it sends out a thread-like growth which penetrates the stigma and goes down through the style, if there is one, to the ovule; and through this little thread or tube something passes into the ovule which stimulates it to develop into seed. Without this element from the pollen an ovule never develops.

(*c*) *Distribution of pollen* — As has been indicated, at least one grain

of pollen must fall upon the stigma, in order to insure production of seed. In a few cases (wheat is believed to be an example), the position of the stigma and the anther in the flower is such that the pollen of that flower fertilizes the pistil of the same flower. Plants whose flowers are fertilized in this way are said to be self-fertilized. Self-fertilization is not the rule among plants. It appears to be unfavorable in most cases to continued vigor and productiveness, just as in-breeding among animals is unfavorable. Accordingly, nature has devised many and ingenious plans whereby the pollen of one flower is carried to the stigma of another flower, and in some cases matters have been so contrived that pollen *must be taken to another plant.* The most common of the agencies whereby pollen is carried from one flower to another are wind and insects. Some flowers are said to be wind-fertilized. In the case of such flowers, the pollen grains are small and dry, so that they are freely moved even by very light currents of air, and as they are wafted through the air they come in contact with the stigma of other flowers, which they fertilize. Indian corn, grasses, and most of the cereal grains are wind-fertilized. The flowers of plants which are wind-fertilized are not bright colored nor fragrant. In the case of those flowers to which insects carry the pollen, the flower is said to be insect-fertilized, and the stigma of such flowers is adhesive. The pollen adheres to some part of the insect and the flower is most ingeniously shaped so that the insect, which

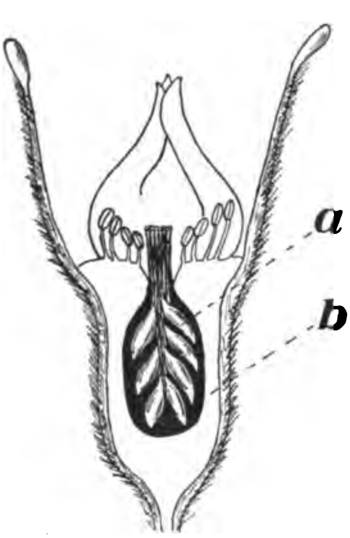


FIG. 96. Section through rose flower; shows pistils at center: *a*, ovule; *b*, protective covering.

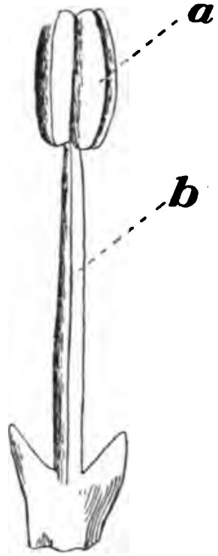


FIG. 97. Stamen from onion flower: *a*, anther; *b*, filament.

has just received pollen on a certain part of its body, is certain to touch that part of the body to the stigma in the next flower it visits. Peas, beans, and clovers may be named among plants whose flowers are insect-fertilized. Such flowers are bright colored or fragrant and secrete honey, for which the insect visits them.

(*d*) *Flowers are of various kinds* — The majority of plants which men cultivate produce flowers which contain all the essential organs. Such flowers are said to be perfect. In some cases the male organs and female organs are produced in separate flowers. Those flowers which produce the male organs are called staminate; those which produce the female organs, pistillate. In some cases both kinds of flowers are produced upon the same plant. Plants of this kind are called monœcious. Among the best examples that can be named among cultivated plants are corn, squashes, pumpkins, melons, and cucumbers. In the case of some species, the staminate and pistillate flowers are produced upon different individual plants. Such species are said to be diœcious. The best examples which can be given among cultivated crops are the hop and hemp.

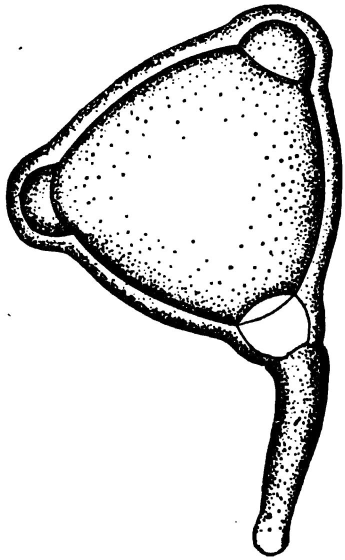


FIG. 98. Single grain of pollen, germinating. Primrose.

473. *The essentials for the production of pure seed* — It has been stated that in order that seed shall be genuine it must be grown under the right conditions (462, *a*). It will now be seen what one of the most important of these conditions must be. The pollen is usually transferred from one flower or from one plant to another. The agencies which carry it may transfer it considerable distances, but, unless the flowers of a given variety receive pollen from the same variety, the seed will be a cross and not a pure product. It is essential that varieties of the same species, when grown for the production of seed, should be separated by such a distance

as is essential to render it improbable that pollen will be transferred from one to the other. This distance varies widely, of course, according to the peculiarities of different species. Wheat of different varieties may be grown close together with little danger of crossing, because self-fertilization is the rule. With corn, comparatively wide separation is essential because the pollen, which is very abundant, light, and dry, is readily carried long distances by the wind. Equally necessary is comparatively wide separation in the case of species which are much visited by insects.

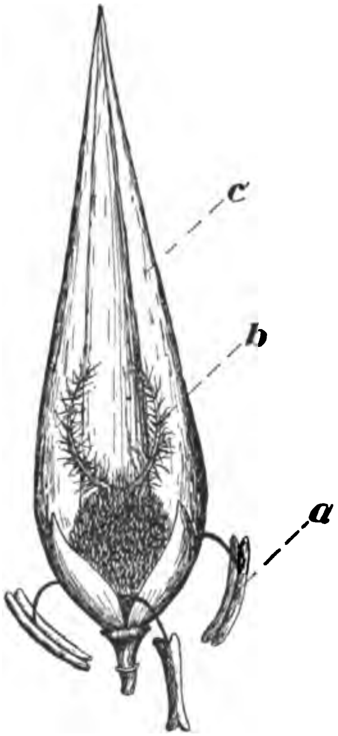


FIG. 99. OAT FLOWER; *a*, stamen; *b*, feathery stigma; *c*, glume.

FIG. 100. Potato showing perfect flowers; *a*, stigma; *b*, stamens.

LXIX — MOWINGS AND PASTURES.

474. *Soils and crops best adapted for mowings and pastures* — While the grasses and clovers found in our mowings and pastures thrive upon a

considerable variety of soils, and indeed may be grown upon soils of almost all classes, it is nevertheless true that the most profitable mowings and pastures are those which have a soil with the following characteristics: it should be deep, retentive of moisture, with a fairly large proportion of clay, well stocked with humus, as well as with the mineral elements of plant food, particularly lime, the presence of which is highly important to the best development of many of the most valuable of the grasses and clovers. It is the so-called perennial grasses and clovers which make up the bulk of the species found in all our mowings and pastures. Some of these, although commonly spoken of as perennial, are, as will be pointed out, comparatively short-lived, and in the case of most of them it is not usually the individual but rather the species which is perennial. The individual dies but is replaced by other individuals of the same species, which are propagated either from seed or from the spreading root.


FIG. 101. MELON. Male flower and section of same.

475. *General characteristics of grasses* — All grasses have fibrous roots which are produced, for the most part, comparatively near the surface. In addition to these fibrous roots, some grasses produce an underground stem, or root stock, as it is called. Witch grass and awnless brome grass are good examples among species having a root stock. The root stock is really, as has been implied in what

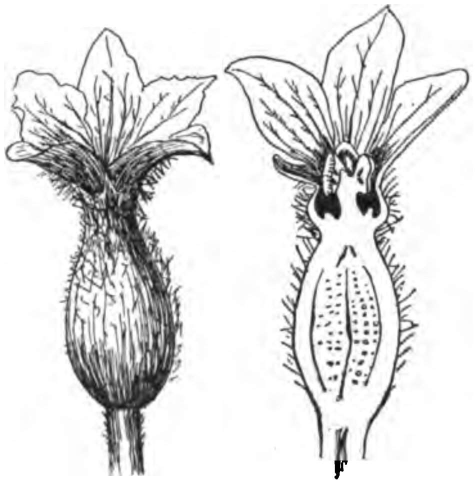


FIG. 102. MELON. Female flower and section of same.

has been said, an underground stem. It is provided with a sharp point, and extends itself nearly horizontally through the ground, a short distance below the surface. Its function is not to gather food from the soil, but to provide for the spread of the species. It is jointed, and at each joint it may send up a new stem and make new roots. This it will often do, even if divided from the parent plant; and this peculiarity renders grasses which have vigorous root stocks comparatively difficult to eradicate. Grasses which develop root stocks form a close turf and are truly perennial. They have the ability to hold the ground with great tenacity and gradually to crowd out other species. Such grasses are generally well suited for use in lawns and in pastures, as they endure close cutting and grazing better than the grasses which have no root stocks. The stems of grasses are hollow with solid joints. From these joints start the leaves, which are usually long and narrow. Other leaves commonly start from the ground. There is great difference between grasses as regards the relative number of leaves from the ground, and from the stem. Lawn and pasture grasses produce a large quantity of root leaves. The hollow, jointed stem, such as is found in grasses and the small grains, is known by the name culm, to distinguish it from stems of other kinds. The culm of most grasses is erect, or nearly so, but there are many species in which the culm bends at the lower end, so that one or more of the lower joints may come into contact with the ground, and several species receive names taken from this characteristic. White bent and Rhode Island bent are examples. When grown on moist soils, grasses having this peculiarity are likely to root at the joints

FIG. 103. HOP. Female plant, flowering shoot.

which touch the ground, and, in this way, such grasses tend to spread and form a turf, which becomes closer and finer with the lapse of time. Many of these species therefore, are sod-forming grasses. The flowers of grasses are for the most part inconspicuous, greenish in color. They are usually perfect and wind-fertilized.

FIG. 104. TIMOTHY GRASS (*Phlĕum pratĕnse*). *A*, plant in flower. 1, flower; 2 and 3, glumes; 5, seed; 1 to 5, magnified.

FIG. 105. AWNLESS BROME GRASS (*Brómus inérmis*). *A*, flowering plant.

From publication of War Department, Germany.

476. *Differences between grasses and plants likely to be mistaken for grasses* — We find growing in mowings and pastures, chiefly where the soil is moist or wet, numerous grass-like plants between which and grasses proper the ordinary observer finds it difficult to distinguish. The most common among these plants are the sedges and rushes. It is quite easy to distinguish between grasses and these plants. The leaves of grasses will be found alternating on two sides of the culm. They are in two ranks or rows. If we start at the bottom with a leaf, we shall find the second leaf on the opposite side of the stem ; the third leaf directly above the first ; the

its own on the deep, moist soils rich in clay, but under average conditions it gradually disappears from mowings and is replaced by species of less value for hay. Timothy produces one heavy crop, but unless conditions are unusually favorable it does not produce much second growth. It is not a sod-forming grass and is very poorly adapted to grazing. The trampling of animals injures the tubers, and if it be closely fed down, especially by sheep or hogs, they will eat the tubers, which seriously weakens and gradually kills out the grass.

FIG. 108. REDTOP (*Agrostis alba*).

FIG. 109. ORCHARD GRASS (*Dactylis glomerata*).

From Bul. No. 14, Div. of Agros., Dept. of Agriculture.

479. *Redtop* (*Agrostis alba, variety vulgaris*) — This species varies considerably, being very similar to the two following; indeed, the three run into one another by intermediate forms to such an extent as to make the distinction between them difficult. Redtop is most at home upon deep and moist soils, but will do better on moderately dry soils than timothy. This grass ranks next in importance to timothy as a hay grass. It blossoms about with timothy, and produces but very little second growth. It is provided with root stocks and will in time make a close turf. It endures grazing exceedingly well, and is a fairly good lawn grass. The seed is very fine, and the grass starts slowly, requiring several years to become fully established.

480. *White bent* (*Agrostis stolonifera*) — This grass resembles redtop very closely, but, as the name indicates, the stems incline to creep along the

ground and to root at the joints where the soil is moist. On such soils this is a fairly valuable grass, whether for mowings or for pasture. It is well adapted for permanent irrigated meadows. Under the ordinary system of farming followed in the Northeastern states, it is less valuable than redtop.

481. *Rhode Island bent* (*Agrostis canina*) — This grass is very variable and much like small plants of redtop. It is far less valuable for mowings than the latter. It starts slowly, and considerable time is required for the formation of a close turf. It is one of the very best of grasses for lawns, and especially on the drier soils it will make a fairly good pasture grass.

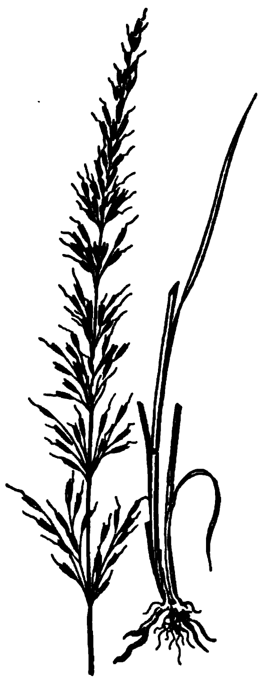


FIG. 110. TALL OAT GRASS (*Arrhenatherum elatius*). *From Bul. No. 14, Div. of Agros., Dept. of Agriculture.*

482. *Orchard grass* (*Dactylis glomerata*) — This is a large, coarse grass on good soils, inclining to grow in tufts, which peculiarity renders the grass unsuited for sowing alone. Orchard grass thrives upon a variety of soils, but will do better upon a moderately dry soil than many grasses. Its period of bloom is about three weeks earlier than that of timothy. This peculiarity makes it far better suited for sowing in mowings with the common red clover than timothy and redtop. The name orchard grass leads many to suppose that this grass grows best in shade. This is not the fact, although it will do better in shade than many other grasses. Orchard grass is valuable both for mowings and pastures. On being cut it starts quickly, producing, on good soils, a heavy second growth, though as a rule it does not flower a second time. The proportion of root leaves is unusually large. The culms are comparatively few. This grass matures so early that it is often allowed to stand until too ripe. Under these circumstances, the hay is usually tough and woody. If cut in good season it is of excellent quality.

483. *Tall oat grass* (*Arrhenatherum elatius*) — This grass will do better on the moderately light soils than many others. The seed is large and it very

quickly takes possession of the ground. It will make a crop within fewer weeks after the seed is sown than almost any other species. It comes into blossom about with orchard grass. It grows after cutting with great rapidity, in the latitude of central Massachusetts giving three crops on good soil in a favorable season. This grass has the reputation of possessing a bitter flavor which, according to some authorities, renders it unpalatable to animals. In the experience of the writer no difficulty from this source has been noticed. All classes of farm animals appear to eat it freely. It is believed that this grass should be more generally grown.

484. *Tall fescue* (*Festuca elatior*) — This grass does best upon the soils which incline to be moist and which are rich in humus. Its season of flowering is midway between that of orchard grass and timothy. It will not come into the best condition for cutting exactly with either, but nevertheless can be grown in mowings with either without serious disadvantage. This grass is a true perennial. It has no root stocks, but the roots tend to sucker and the tufts to spread from year to year. The root leaves are very abundant. The culm is tall and moderately coarse. The grass is valuable both for pastures and mowings. The seed is large, the grass covers the ground quite quickly. The second growth, provided the soil and season are favorable, is considerable.

485. *Meadow fescue* (*Festuca elatior, variety pratensis*) — This grass is very similar in respect to soil adaption and general characteristics to the tall fescue. The chief difference is that it is not quite so tall and coarse. It is a very valuable grass on the moderately moist soils, both in pastures and mowings.

486. *Reed fescue* (*Festuca elatior, variety arundinacea*) — This is a very vigorous form of the tall fescue. It is suited to quite moist soils, on which it often reaches the height of 3 or 4 feet and gives heavy yields of valuable hay. Except for its larger size, it is in all respects very similar to the tall fescue.

487. *Sheep's fescue* (*Festuca ovina*) — This is a very small grass, quite variable and occasionally reaching a fair size. It however rarely grows over a foot in height and has a habit of forming tufts, whence it is called

bunch grass by some. These tufts, which soon become higher than the general surface, tend to increase in size somewhat from year to year, but this grass does not spread to such an extent as to form a fine, close turf. It thrives upon drier soils than many other grasses, and on such soils may possibly prove valuable for sheep pastures. It can never prove of much value in mowings, and on the whole must be regarded as comparatively unimportant.

488. *Red fescue* (*Festuca rubra*) — Red fescue is in many respects similar to the sheep's fescue. It is suited to the same kind of soil and has the same general appearance. It however develops root stocks and forms a close and durable turf. It produces a large quantity of root leaves. Because of these characteristics, it is more valuable in pastures than sheep's fescue. It is also sometimes recommended for shady lawns, as the turf, on account of the narrowness of the root leaves, is very fine and beautiful under the best conditions. This grass is too small to prove valuable in mowings.

FIG. 111. REED FESCUE. (*Festuca arundinacea.*) *From Bul. No. 14, Div. of Agros., Dept. of Agriculture.*

489. *Slender fescue* (*Festuca tenuifolia*) — This grass is much like sheep's fescue, of which many regard it as simply a variety. The seed is kept by most seedsmen, but the conditions must be very rare when it will pay to sow this grass.

490. *Kentucky blue grass* (*Poa pratensis*) — This is the "June" grass of many localities. Kentucky blue grass is especially suited to moderately heavy, deep soils, retentive of moisture, and rich in lime. It produces abundant root stocks, is a true perennial, and has the ability on suitable soils gradually to crowd out many of the common English grasses. Old mowings, in many cases, come finally to contain very little except Kentucky blue grass, although no seed of this variety may have been sown. The soil is

stocked with the seed in many localities to such an extent that it gradually comes in of itself, and, spreading by means of its vigorous root stocks, finally displaces almost everything else. Kentucky blue grass produces a very large proportion of root leaves, and comparatively little culm. It blossoms about with orchard grass, *i. e.*, some three weeks earlier than timothy. It is the most valuable of all the pasture grasses under average conditions in the Northeastern states. It is by no means of equal value for mowings. Under the best conditions, it reaches about the same size as redtop, but this grass is injured, throughout the region under consideration, to a very great extent by one of the thrips, an insect producing a maggot-like larva which lives in the stem just above the upper joint, feeding upon the stem inside the leaf sheath, and causing the top of the grass to die, when it soon turns light or almost white. The attack of this insect prevents the grass from reaching full development, and seriously lessens the yield of hay. Kentucky blue grass produces hay of excellent quality, well fitted for home use, but it is not nearly as salable as the hay of coarser grasses. Moreover, when cut, Kentucky blue grass produces but little rowen. Because of the peculiarities to which attention has been called, the writer is not inclined to recommend the use of this grass in mowings. It should, however, be sown in pastures where the soil is of the kind which has been indicated. This grass is also one of the best of the lawn grasses.

FIG. 112. KENTUCKY BLUE GRASS (*Poa pratensis*). *From Bul. No. 14, Division of Agros., Dept. of Agriculture.*

491. *Canada blue grass* (*Poa compressa*) — This grass is very closely related to Kentucky blue grass, but can be easily distinguished from it by its much flattened stems. It has many creeping root stocks, and forms a

close, strong turf. Other characteristics which serve to distinguish it from Kentucky blue grass are its more decidedly blue color, lower habit of growth, and smaller head. It thrives upon a great variety of soils, even upon those so poor that most other grasses fail. It is an excellent pasture grass for the Eastern and Middle states, on dry and poor soils. On rich soils it may yield a fairly good hay crop. It shrinks less in drying than almost any other grass, as the culm is unusually solid.

492. *Fletcher's blue grass* (*Poa Fletcherii*) — Professor Fletcher, of the Ontario Experiment Station, has sent out a type of grass closely resembling Kentucky blue grass, but much more vigorous in its habit of growth. Results obtained on the grounds of the Massachusetts Agricultural College indicate that this may prove somewhat more valuable, both for pastures and mowings, but especially for the latter, than the ordinary Kentucky blue grass.

493. *Fowl meadow* (*Poa serotina*) — This grass is native to the United States, and is found chiefly on the low, moist lands in the Eastern and Northern United States. It flowers about the same time as timothy. This grass has no root stocks, but on moist soil or in damp weather inclines to branch at the lower joints, and these branches to take root. In this manner the grass spreads and forms a close turf. The proportion of culm is much larger than with Kentucky blue grass, and the head is longer and heavier, the stem slender. On this account, if sown alone, this grass is very liable to lodge. The stems remain green and succulent much longer after flowering than is the case with most grasses. On this account it is less necessary to cut early in order to secure hay of good quality. It is believed that this grass should be more generally sown on the rich, moist soils for mowings. The yield is heavy, the hay fine, and of high nutritive value. It does not make much second growth. It should not be sown alone, on account of its liability to lodge. The seeds are very small and the grass is comparatively slow in occupying the ground.

494. *Rough-stalked meadow* (*Poa trivialis*) — This grass differs from Kentucky blue grass, to which it is closely related, in having no root stock and a stem which is distinctly rough. It produces abundance of root leaves

and is regarded as a good grass for permanent pastures on moist, cool soils. It is not a good mowing grass.

495. *Meadow foxtail* (*Alopecurus pratensis*) — This grass is cultivated to some extent in the Northeastern states. It is regarded in many parts of Europe as one of the most valuable grasses, especially for pastures where the soil is moist and rich. According to the observation of the writer, it does not, as a rule, do particularly well in the latitude of central Massachusetts. The weather appears to be too dry to suit it. In moist seasons it has given abundant crops, but when the season is dry the crop is unsatisfactory. It is one of the earliest of all grasses, beginning to blossom in central Massachusetts, in average years, by about May 25, and it is particularly on account of its early growth that many recommend it for use in pastures. In general appearance, this grass somewhat resembles timothy; but the heads, instead of being cylindrical as in timothy, are thicker near the middle than at the ends. They are also rather soft and woolly, while those of timothy are harsh and rough to the feel. As meadow foxtail flowers a full month earlier than timothy, there is, therefore, no difficulty in distinguishing between the two. This grass starts very quickly after cutting, and in moist seasons has given three fair crops in central Massachusetts. The seed is very light, weighing only about seven pounds to the bushel, and usually germinates poorly. Though this grass is often recommended, the writer, taking into account all its peculiarities, concludes that it is not likely to prove of much value in the Northeastern states.

FIG. 113. MEADOW FOXTAIL (*Alopecurus pratensis*). From *Bul. No. 14, Div. of Agros., Dept of Agriculture.*

496. *Sweet vernal grass* (*Anthoxanthum odoratum*) — This species is in some localities known as "June" grass. It is one of the earliest of the common grasses to come into flower. On wilting, it gives off a very characteristic and delightful odor, and on this account it has often been recommended on the theory that it would impart fine flavor to dairy products.

The results of investigation do not support this theory, and, in spite of the fact that the fragrance of the grass is so agreeable to man, it is not much relished by stock, as the leaves have a bitter taste. The grass comes in to old mowings in many parts of the country. It is not believed that it will ever pay to sow it. There is an annual form of this species which is much smaller than the perennial, and absolutely of no value. Seeds of this are sometimes sold in place of the seeds of the perennial variety.

FIG. 114. PERENNIAL RYE GRASS (*Lolium perenne*). *From Bul. No. 14, Div. of Agros., Dept. of Agriculture.*

497. *Perennial rye grass* (*Lolium perenne*) — This species is sometimes also known as English rye grass. This is a favorite grass in England, where it has long been cultivated. Some authorities believe it is the very first grass gathered and cultivated for agricultural purposes. This grass has often been highly recommended by American writers and seedsmen, but, while doubtless valuable in England, the fact appears to be that the climatic conditions in this country are far less suited to its development than those prevailing in England. The grass flowers about with orchard grass. It is adapted to moist and moderately heavy loams. It produces a large amount of root leaves, and under the best conditions a heavy growth of stem as well. There are several varieties, among which Pacey's perennial is one of the best. The seed is large, germinates quickly, and the grass quickly covers the ground. It is not as hardy as most of the grasses which have been described, and in the latitude of central Massachusetts sometimes seriously winterkills. In spite of its name, perennial, it proves a rather short-lived grass in the locality just named. The writer does not consider it of much value, although it may pay to sow small quantities of it in mixture with early varieties like orchard grass or tall oat grass, for the sake of its influence in increasing the yield for the first year or two, as it occupies the ground more quickly than orchard grass.

498. *Italian rye grass* (*Lolium Italicum*) — This, in most respects, closely resembles the perennial rye grass, but is supposed to be shorter lived. Experiments on the grounds of the Massachusetts Agricultural College have not shown much difference in that respect between the two, and on account of the larger size and quicker growth from seed the Italian rye grass is recommended as superior to the perennial. Few grasses will produce a crop in so few weeks from seed; few start so quickly after being cut, three good crops in a year on moist, rich soils and in favorable seasons being the rule. The hay from this grass is moderately coarse. It cures easily. It is believed that this grass would prove valuable under sewage irrigation, as it seems better able to make use of the abundant food and moisture supplied thereby than most other grasses. It is very well adapted for use as a soiling crop. It should never be sown in pastures, but for mowings it may be used to increase the crop for the first year or two by sowing in mixture with orchard grass, tall oat, and meadow fescue.

499. *Witch or couch grass* (*Agropyron repens*) — This grass is abundant throughout the Middle and New England states, where it is in many places one of the most serious pests of cultivated fields. It owes this quality to its very vigorous, wide-spreading root stocks which render it very difficult to kill it out. This very peculiarity, however, may render the grass especially adapted to certain uses. It thrives on the light and medium loams. It is moderately coarse, easily cured, and has a great tendency to become tough and woody after flowering. To make good hay it must be cut early. The grass is truly perennial, but on account of the abundant root stocks which keep sending out new stems it "binds itself out," *i. e.*, it becomes overcrowded, the growth becomes comparatively feeble, and the yield small. The sod must be broken up once in two or three years to restore the yield. This is one of the best grasses which can be used for holding railway or other embankments subject to wash. It can be propagated either from seed or from root cuttings. On account of the difficulty of eradicating it, the writer does not recommend this grass to be sown for any ordinary farm purpose.

500. *Blue joint grass* (*Calamagrostis canadensis*) — This is a native

grass which is very seldom sown but is found in many parts of the northern United States, growing in moist soils, especially in the so-called fresh marshes. It sometimes takes entire possession of limited areas; and, where it thus becomes the only species, it produces very heavy yields of forage of greater value than that usually furnished by the other plants which grow in such marshes. It frequently reaches a height of from 5 to 6 feet. It flowers comparatively early and should be cut soon after it flowers to make the best hay. As it will give a larger yield than almost any other grass and the nutritive quality is good, it would seem that it should be more frequently sown on such soils as suit it. It is a hay and not a pasture grass.

FIG. 115. BLUE JOINT (*Calamagrostis canadensis*). *From Bul. No. 14, Div. of Agros., Dept. of Agriculture.*

501. *Yellow oat grass* (*Trisetum pratense*) — This grass has been introduced from Europe and is often recommended for culture. It has as yet received but little attention in this country. It thrives on medium loams and will make a crop on soils that are drier than those suited for most grasses. It is better suited to mowings than to pastures. It flowers about with orchard grass.

502. *Meadow soft grass* (*Holcus lanatus*) — This is a grass characterized by somewhat velvety leaves and leaf sheaths, whence its name. It is common in old mowings, but is not relished by stock and is comparatively valueless.

503. *Awnless brome grass* (*Bromus inermis*) — This grass is comparatively new to the agriculture of the United States. It belongs to the same genus with a number of pernicious annual species, generally known under the common name chess or cheat. This species, however, is perennial. It is said to be capable of making a profitable crop on lighter soils than most grasses, and to have unusual ability to resist drouth. It develops numerous root stocks and quickly makes a thick, firm turf. It is recommended as likely to prove valuable both for pastures and mowings. It is reported to be difficult to eradicate as it has somewhat the same habit as witch grass.

As the result of such experiments as have come under the writer's eye, he is not inclined to believe that this grass will prove a very decided acquisition, although it is believed to be worth a trial.

LXXI — PERENNIAL CLOVERS AND ALFALFA.

504. *Clovers* — There is a considerable number of species of perennial clovers known to botanists, but only a few of these seem likely to prove valuable, either in pastures or mowings; and these are in general well known and will be but very briefly spoken of. It will be remembered that all clovers are legumes and have the very valuable property of taking from the air much of the nitrogen they need, when grown under proper conditions. The perennial clovers are commonly considered with grasses, with which they are very generally grown. Although put to the same uses, they differ from the grasses in marked degree in their habit of growth and in their botanical characteristics, as well as in their nutritive value. Clovers have a long tap root, branching considerably. Their flowers are borne in heads and contain a large amount of honey, which attracts insects and they are, accordingly, insect-fertilized. The common bumblebee is the most common insect concerned in the fertilization of red and mammoth clovers, while the honey bee visits the white and alsike clovers. The tubular flowers of the red clover are so long that it is impossible for the honey bee to extract the honey from them. It is believed that it may be possible to shorten the tube in these clovers by careful selection and breeding, so that the honey bee can reach the bottom, or possibly to produce by careful breeding, a honey bee with the sucking organs sufficiently long to enable him to reach the honey in these clovers. It is very desirable that one or the other of these results should be attained, for it would render the fertilization of the flowers of the clover much more certain, and would add a most valuable plant to the list of those used for bee pasturage.

505. *Red clover* (*Trifolium pratense*) —This is a biennial or short-lived perennial. The stems, which reach to the height of from 1 to 2 feet, according to the fertility of the soil and climate, branch moderately. The upper surface of the leaves shows a very characteristic pale spot. The

heads are large, round, and the flowers pink. This clover, to do its best, requires a deep, fertile soil, rich in lime, and moderately retentive of moisture. On soils which are too clayey it is liable to winterkill. On the very light soils it suffers from drouth in summer. Red clover starts quickly on being cut and will give from two to three crops per season in the latitude of central Massachusetts. Two crops are the rule ; but, if the first and second cuts are made comparatively early, if the season is favorable and the soil rich, a considerable third crop may be produced. Red clover begins to blossom about with orchard grass and will blossom continually throughout the season, even if not cut. It reaches the best condition for cutting earlier than timothy, with which it is often sown. It is better suited for sowing with orchard grass than with timothy, as the two species mature at about the same time.

FIG. 116. RED CLOVER (*Trifolium pratense*). *A*, flowering plant; 1 and 2, flowers; 3, calyx; 4, section of flower; 5, stamen; 6, pistil; 7, husk of seed; 8, seed; 1 to 8, magnified.
From Pub. of War Dept., Germany.

506. *Pea vine clover* (*Trifolium pratense, variety perenne*)— This variety of clover closely resembles the red but has more hairy leaves, weaker stems, and larger blossoms. It is larger and better for soils inclined to be wet than common red clover.

507. *Mammoth clover* (*Trifolium medium*)— This closely resembles red clover, but is a somewhat larger plant and has narrower leaflets, which are without the pale spot found on the leaflets of red clover. This clover flowers somewhat later than red clover and is better suited for sowing in mixtures with timothy on that account. It will also do somewhat better on wet soils than the common red clover.

508. *Alsike clover* (*Trifolium hybridum*)— This combines many of

the characteristics of the red and white clovers. It has the stem and general habit of growth of the red clover, although it is not quite so coarse. The shape of the head is like that of the white clover. The color of the flower is a light pink. This is a most valuable clover for mowings on soils which are rather too moist for red clover. It flowers somewhat later than that clover, is better suited for use in mixture with timothy. Being finer than red clover, it cures more readily and makes more palatable hay.

FIG. 117. ALSIKE CLOVER (*Trifolium hybridum*). *From Bul. No. 2, Div. of Agros., Dept. of Agriculture.*

FIG. 118. WHITE CLOVER (*Trifolium repens*). *From Bul. No. 2, Div. of Agros., Dept. of Agriculture.*

509. *White clover* (*Trifolium repens*) — The stems of this clover have a creeping habit of growth, and if the soil is moist they send out roots where they lie close to the ground and the clover spreads rapidly in this way. This habit of the plant renders this clover truly perennial. It also rather unfits it for use in mowings. Its presence in mowings may cause a

very thick growth at the bottom, and considerably increase the yield and the nutritive value of the hay; but on the whole this clover is not one which should generally be sown in mowings. It is the best pasture clover. A close sod, consisting chiefly of Kentucky blue grass and white clover, makes an ideal pasture. This clover is also commonly used in lawns, although some prefer a lawn composed of grasses only. White clover is capable of growing on a great variety of soils, but will do best on those which are moderately retentive of moisture.

510. *Alfalfa* (*Medicago sativa*) — Alfalfa, though belonging to a different genus, resembles the clovers in many important particulars. Like them it has a very long tap root. On suitable soils it is, indeed, the deepest rooting of all forage plants. Where the subsoil is not too compact and is free from standing water, the roots strike down to the distance of ten or twelve feet in many cases, and sometimes considerably deeper. In nutritive value the alfalfa surpasses even clovers, being richer in flesh-forming materials, and is highly relished by all kinds of stock. Alfalfa is a very long-lived perennial when grown in soils and climates that suit it. In the region between the Missouri river and the Rocky mountains and in California it is by far the most valuable forage and hay crop grown. In the Northeastern states alfalfa is much less at home. The subsoils are often too compact and in many cases the water table is too near the surface. The climate, too, in those parts of the region under consideration, where the winter snowfall is light, is unfavorable to alfalfa. Alfalfa is, as a rule, grown by itself, whether as a pasture crop, for green forage, or for hay, though it is sometimes included in mixtures of grasses and clovers both for mowings and pastures. Alfalfa is smaller and more feeble than clovers at start and must be sown in clean soils or it will require cultivation or weeding. The quantity of seed needed varies from twenty to thirty pounds to the acre under Massachusetts conditions. Much less answers in the west. When once established in soils which suit it and under favorable climatic conditions, alfalfa will yield three or four crops yearly. It endures drouth when well established far better than most crops. It should be manured or fertilized in the same manner as clovers. Lime in abundance appears to be more essential for this crop than for the clovers. During the last few years the

attempt to grow alfalfa in the northern New England states has been attended with a fair degree of success. It is being increasingly grown in New York and the other Middle states and is considerable grown in some parts of Canada, where the winter snowfall is heavy.

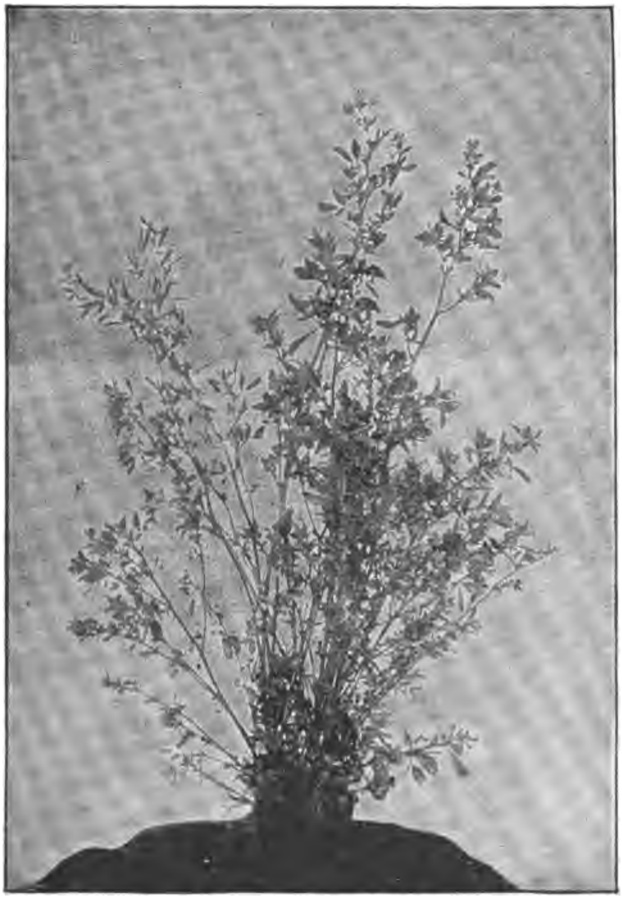


FIG. 119. ALFALFA, SINGLE PLANT. *After Shaw.*
Courtesy of Minnesota University Experiment Farm.

LXXII — SEEDING AND CARE OF MOWINGS.

511. *Grass and clover seeds* — There is a very wide difference in the seeds of grasses, both as regards size and the shape in which they are put

upon the market. Some can be readily separated from the chaff, and, as offered in our markets, are clean and usually of good quality. The seeds of timothy, redtop, and the clovers are of this type. In the case of many grass seeds no practical method of separating from the chaff has been perfected; and, as offered in our markets, these seeds are very light and much mixed with material which has no possible value and may be injurious. They often germinate very poorly and they are difficult to sow. Meadow foxtail and sweet vernal are examples. In the case of those seeds which are universally and largely used, there is comparatively little fraud; but the seeds of many of the kinds of grasses which have been described are not well known to farmers, and many of them on cursory examination resemble each other quite closely, being of very similar shape and size. In the case of some of these seeds there appears to be considerable fraud; seeds of cheaper species, cheaper because the seed is more abundantly and therefore more cheaply produced, being apparently sometimes substituted for the seeds of the most costly kinds. The seeds of orchard grass and those of rye grasses look much alike, and as the rye grass seed can be much more cheaply grown than that of orchard grass it is sometimes mixed with the latter. The seed of chess is of the same general shape and size as that of orchard grass, and this is sometimes mixed with the latter. Close examination reveals differences between these seeds which can be easily made out with a magnifying glass, and it is believed that the illustrations given herewith will enable the farmer to distinguish between them. Weed seeds of various kinds are frequently found mixed with grass seeds and against these also the farmer should be on his guard. The farmer who would purchase any of the less known varieties of grass seed should deal only with a reliable firm which has a good reputation, and whose interest it is to maintain that reputation. Cheap grass seeds are likely to prove the dearest in the end.

It is seldom best to sow any one of the varieties of grass or clover alone. Mixtures containing a number of species will almost invariably give more satisfactory crops. Nevertheless, for the purpose of raising seed or under special conditions the farmer may sometimes wish to put a variety by itself. For the guidance of those who may wish to do this,

a table is here presented which shows the number of pounds of seeds of the different kinds contained in one bushel, the number of seeds in one ounce, and the approximate quantity of seed required per acre. The table shows also the approximate dates of flowering of the several species as observed in central Massachusetts. In making up mixtures for mowings, some knowledge as to the date of flowering is essential, since only varieties which bloom at nearly the same time should be put together.

	Pounds to Bushel.	Number Seeds to Ounce.	Pounds Required When Sown Alone.	Approximate Dates of Flowering in Central Massachusetts.
GRASSES.				
Timothy	45	74,000	25	July 1–10
Redtop	14	425,000	42	July 6–15
White bent	20	500,000	40	July 6–15
Rhode Island bent	14	....	42	July 6–15
Orchard grass	14	40,000	45	June 10–20
Tall oat grass	10	21,000	45	June 10–20
Tall fescue	15	20,500	35	June 20–30
Meadow fescue	15	26,000	55	June 20–30
Reed fescue	..	....	..	....
Sheep's fescue	12	64,000	30	June 10–20
Red fescue	10	39,000	35	June 10–20
Slender fescue	15	80,000	42	June 10–20
Kentucky blue grass	14	243,000	42	June 10–20
Canada blue grass	..	....	..	June 20–30
Fletcher's blue grass	..	....	..	June 10–20
Fowl meadow	..	....	..	July 1–10
Rough-stalked meadow	14	217,000	22	June 25–July 5
Meadow foxtail	7	76,000	25	May 20–June 10
Sweet vernal	10	71,000	35	June 5–15
Perennial rye grass	18–30	15,000	60	June 10–20
Italian rye grass	18–20	[illegible]	54	June 10–20
Witch grass	..	....	..	July ....
Blue joint	..	....	..	July ....
Yellow oat	7	....	21	June 20–30
Meadow soft	6	85,000	..	June 20–30
Awnless brome	14	....	35	June 10–20
CLOVERS.				
Red	60	16,000	15	June 10–Sept.
Pea vine	60	16,000	20	June 20–Sept.
Mammoth	..	....	20	July–Sept.
Alsike	60	45,000	12	June 25–Sept.
White	60	32,000	8	May–Sept.

512. *Seeds of some species usually germinate well; others do not* — As a rule, the seeds of all the common grasses germinate well. Among such seeds, the most reliable are those of timothy, redtop, orchard grass, Kentucky blue grass, and all the clovers which have been described. On the other hand, the seeds of the less common grasses which have been described often possess a very low vitality, and only a small proportion can be counted upon to germinate. This is specially likely to be true of many of the fescues, tall oat grass, yellow oat grass, sweet vernal, and meadow fox tail. These seeds are usually imported from Europe. The fact that these less known seeds are so likely to be adulterated (462, *b*), and that so small a proportion, in many cases, germinates, greatly increases the difficulty and the cost of effecting any improvement in our mowings through the introduction of the less known varieties of grass.

513. *Selection of seeds for mowings* — As has been indicated (511), it is almost invariably best to put together a number of species for mowings. Universal experience indicates that the yield is greater with a considerable number of species than with one or a few only. A large number of species forms a close sod, one species helping to fill in the spaces naturally left between the individual plants of others. The number of mixtures advised for use in mowings is very great, and hardly any two authorities will be found to agree. It is hardly to be expected that any possible mixture will be universally suitable. It is proposed, however, to call attention to the important points which should be considered, in deciding upon the varieties and quantity of the different kinds to be used, and to call attention to a few mixtures which have been found suited to conditions which are frequently met with.

1st. The species which are to be sown together for mowing should all flower at approximately the same time. This is essential, in order that all may reach that degree of maturity desired at nearly the same time. If early and late species are included in the same mixture, it is evident that some must be overripe or insufficiently matured when cut. Seedsmen not infrequently lose sight of the importance of the points to which attention has been called, including in the same mixture some of the earliest as well as some of the latest of varieties.

2d. In making a selection, the farmer should consider the suitability of the different species for his soil. In the brief description which has been given, the kinds of soil on which the different species thrive have in most cases been indicated. The importance of observing this rule is evident, without further discussion.

3d. It is believed that it will generally be found better to buy the different species of grasses and clovers desired separately, rather than to purchase ready-made mixtures. The chief reason is because there is less opportunity for fraud. The farmer should know the appearance of seeds of the different varieties ordered; and, buying each by itself, he can then determine by examination whether it is genuine. In case of doubt samples can be sent to the experiment station. Where seeds are purchased in mixtures, the constituent species of which are unknown, it is impossible to determine whether the kinds included are suited to the purpose for which they are desired. True, if a ready-made mixture recommended by a responsible firm for a special purpose is purchased, the chances are that it will be found suited to that purpose. Still, since there is such opportunity for deception in these mixtures, it is believed that they should be avoided.

514. *The usual farmers' mixture* — Comparatively few of our farmers sow any other species than timothy, redtop, and clover, — most usually red clover, though here and there a farmer selects alsike clover or uses alsike clover in part. Where this mixture is sown, the cost of seeding is comparatively low. The first year the crop is mainly clover, the second year timothy is found in very large proportion, and the third and following years redtop becomes more prominent; and, if the mowing be allowed to to lie longer, indigenous species, such as Kentucky blue grass in many sections, sweet vernal in others, gradually come in and replace the timothy unless the soil is particularly adapted to the latter and the manuring be heavy, when it may persist for a number of years. By the use of this mixture the farmer produces the first year hay well fitted for feeding at home; the second and later years good market hay. The seeds of these species being in large demand, and therefore handled by growers and dealers in large quantities, are cheaper than the others and, as has been pointed out,

more reliable. Among all the mixtures which the writer has seen tried, he has found none which he is inclined to recommend for general adoption in place of this standard mixture. He would, however, urge the use of mammoth clover in place of the common red, since it blossoms more nearly with timothy. The quantities of the different seeds used should vary in individual cases. It is believed that heavy seeding is generally advisable, as the mowing will be more free from weeds, and the writer recommends the following :—

Timothy,	18 lbs.
Redtop,	8 "
Mammoth clover,	5 "
Alsike clover,	4 "

515. *Other mixtures recommended for special purposes.*

	For 2 or 3 Years' Mowing.			Permanent Mowings.		
	Light Soils. Pounds.	Medium Soils. Pounds.	Heavy Soils. Pounds.	Light Soils. Pounds.	Medium Soils. Pounds.	Heavy Soils. Pounds.
Timothy	..	..	10	..	..	6
Redtop	..	..	6	..	..	8
Orchard grass	12	14	..	15	8	..
Tall oat grass	..	6	..	5	..	..
Italian rye grass	5	4	4	3	3	..
Perennial rye grass	..	..	4	3	..	..
Yellow oat grass	..	..	..	..	4	..
Kentucky blue grass	..	..	..	..	..	4
Meadow fescue	..	6	5	..	5	6
Tall fescue	..	..	4	..	5	4
Red fescue	2	..	..	..	..	..
Awnless brome grass	8	..	..	5	..	..
Red clover	8	6	..	6	5	..
Mammoth clover	..	..	4	..	..	5
Alsike clover	..	2	4	..	4	4
White clover	..	..	..	2	..	..

516. *Time and manner of sowing* — Grass and clover seeds for mowings have been sown at almost every season of the year successfully and there is something which can be said in favor of each. Some of the more important considerations are as follows :—

(*a*) *Spring sowing* — Grass and clover seeds start well in the cool, moist weather likely to prevail in early spring ; but weeds start abundantly

from seed at the same season. In order to keep down the growth of weeds as well as for the purpose of obtaining a fodder or grain crop, farmers are accustomed to sow some grain with the spring-sown grass seeds. Under these circumstances, at the time when the grain is harvested, whether as a fodder crop or when ripe, the young grass and clover plants exposed to the full, strong light of the sun at the hottest time in the year are very liable to injury. Not infrequently the seeding which has started in a very satisfactory way is destroyed within a week or ten days after the cutting of the grain crop. For this reason chiefly spring sowing is not advocated.

FIG. 120. MOWING. Ordinary farmer's mixture, timothy, redtop, and clover. First year, a little volunteer rye.

(*b*) *Seeding in the corn field*— Among all the various methods which the writer has tried for seeding to grass and clover, he has found the system of sowing in growing corn at the time of the last cultivation, usually from July 20 to August 5, to give most satisfactory results. The culture of the corn must be level, and it must be kept free from weeds. Just previous to sowing the seed, a spike-tooth cultivator should be used, which will leave the surface fine and mellow. The quantity of seed used should be rather larger than may be required when it is sown alone, as a part of it fails to reach the ground, being caught and retained by the broad leaves of the corn. Dog-day weather should be selected for sowing the seed; and, if it can be scat-

tered upon the freshly cultivated surface just before one of the heavy showers which occur so frequently during dog days, the seed will need no covering and will often have germinated within forty-eight hours from the time of sowing. The shade of the corn crop is favorable to the retention of moisture and on all except the driest soils there will be moisture enough to keep the young plants growing. The corn protects from the sun but does not crowd. It is not likely to lodge and stifle the young grass as a crop of small grain

FIG. 121. RESULTS OF SEEDING IN CORN. Seeds sown last of July, first year. The mixture of seeds is that given in table, page 425, under "For Two or Three Years Mowing — Heavy Soils."

so often does. It is preferable that the seeding be done in a crop of corn destined for the silo. This being carried from the field at once, the grass has the most favorable time of the year to spread and gather strength for the winter. If the corn is grown for grain and must be stooked, there is no great difficulty; but the young plants will be killed where the stooks stand, and these spots must be reseeded either late in autumn or early the following spring. Grass and clover sown in accordance with the method just

described become fully established before winter and are less liable to injury than when sown later. They become sufficiently strong to give a full crop the following year. It is best that the corn be cut low and the field should be rolled the following spring as soon as it becomes sufficiently firm not to be cut up by the horses. Rolling at this time breaks down the corn stubble, which is at that time brittle; and it will be noticed in the hay to a less extent even than is the stubble of a small grain.

(*c*) *Fall sowing* — When fields can be cleared of crops not later than about the 15th of September in the latitude of central Massachusetts, grass and clover seeds may safely be sown, unless the soil is of a character likely to heave, in which case it will not be safe to sow clover as late as indicated. At this season of the year if grass and clover seeds are sown alone annual weeds no longer prove troublesome. The chief objection to this method of sowing is, that the plants do not become sufficiently well established before winter, to be certain to go through without injury, unless indeed the field can be cleared earlier than is usually possible. If the seed can be got in not later than about August 20th in the latitude of central Massachusetts, this is usually a good season for sowing, although not infrequently the late summer and early autumn months are so dry that the grass does not make a good start. If it is found impossible to fit land for fall sowing until much after the first of September, it will be best to defer putting in clover until the following spring, for the reason that the young plants are not likely to become sufficiently rooted to pass through the winter safely, if sown much after the date mentioned. The clover should be sown as soon as may be after the winter frost is out of the ground, and, if possible, some still morning when the surface is frozen to the depth of half an inch or so, and when rain seems probable. If sown under these conditions, clover seed is carried into the earth sufficiently to make a quick start. A light snow on the ground assists greatly in evenly distributing the seed, and melting may help to carry it into the soil.

(*d*) *Late fall sowing* — Some advocate preparing the ground and putting in the seed just before the ground freezes, in the expectation that it will lie dormant until spring, when it will start into growth earlier, and

therefore under more favorable moisture conditions, than can be counted upon if sowing be deferred until spring. Both grass and clover seeds can be sown at the same time under this system. Against this system may be urged that if the field has any slope it will be particularly liable to washing, as the smooth surface invites injury from this cause. A considerable loss of the fine particles of soil through the action of the wind is also likely to take place in many locations. The writer is not inclined to recommend this system.

(*e*) *Should grass seeds be sown alone or with grain?* — In discussing the different seasons at which land is seeded to grass, some hints have been given bearing upon this question. There can be no doubt that, if weeds can be kept down, grass will make a better start if sown alone, but as a matter of fact, under the conditions usually existing, weeds are sure to make a vigorous start with the grass seeds whenever the latter are spring-sown. Accordingly, most farmers prefer to sow with them some grain, and in the Northeastern states this is most commonly oats. Whether oats or any other grain, the quantity of seed should be relatively small, for if the grain be thick the grass is stifled, the grain is more liable to lodge, and the young grass and clover plants beneath it are killed. From a bushel and a half to two bushels to the acre are sufficient. If grain be sown it is best that it be cut early and either fed green or made into hay. If allowed to ripen, it draws so heavily on the soil, both for plant food and for moisture, that the grass and clover are enfeebled. When grass is sown in mid-autumn, it is quite common to sow it with grain — winter wheat or rye. It is unnecessary that grain be sown with it at this season, for there is not likely to be much growth of weeds; but, as a matter of farm economy, it may seem best to sow with the grain. If this is to be done, it should be remembered here, also, that the grain should not be sown too thick. Both rye and wheat should, as a rule, be sown so late that it will be unsafe to put in clover at the same time. The clover seed must be sown in the grain the following spring, at the period and under the weather conditions which have already been indicated (516, *c*).

(*f*) *Machines for sowing grass seeds.* 1st. If grass seeds are sown with grain, it is common to put them in with the drill, which sows the grain

in those parts of the country where grain is extensively grown. All grain drills are made with grass seeding attachments. These machines will not, however, sow the coarse or chaffy seeds in a satisfactory manner. They distribute seeds of such species as timothy, redtop, and clover more evenly and more satisfactorily than can be done by hand. Some grain drills are provided also with a fertilizer attachment and grain, grass seed, and fertilizers are all put in at one operation.

Fig. 122. Grain Drill, which sows fertilizer and grass seed at the same time with grain, if desired.

2d. Broadcast seeders. There are numerous machines made, in both hand and power sizes, which sow grass seeds broadcast in a very satisfactory manner. These machines, of which Cahoon's is a type, will sow chaffy as well as thoroughly cleaned seeds. The seed is, however, thrown so high in the air that satisfactory results can be obtained only in moderately calm weather.

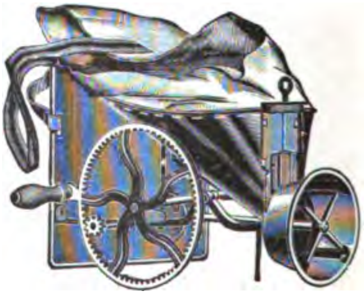


Fig. 123. Cahoon Seed Sower

3d. Wheelbarrow seeders. Seeders of this type do very satisfactory work with all the thoroughly cleaned seeds, but cannot be depended upon to sow the coarse seeds such as orchard grass or any of the chaffy seeds.

4th. Hand sowing. Grass seeds can be so rapidly sown by hand, and by practice so evenly distributed, that there is not any very decided saving in cost by the use of any of the machines named.

5th. Covering grass seeds. A considerable proportion of grass and clover seeds may germinate in soil which has been made mellow, without covering, but in the majority of instances moderate covering is desirable.

Weeders designed primarily for intertillage (188) will do this work in a satisfactory manner. In many cases the roller will cover the seed sufficiently; and even when the weeder or the old-fashioned brush is first used it is commonly best to finish with the roller.

517. *Manures and fertilizers to be used when seeding mowings* — It will, as a rule, be found best to use manures or fertilizers rather freely in the cultivation of crops which precede grass, and to depend upon the store of fertility in the soil at the time of seeding. If, however, for any reason this has not been done, or if the grass follows a crop which has left the soil somewhat exhausted, either manure or fertilizer should be used at the time of sowing. If fine manure is available there is nothing better. If fertilizers are to be used the selection of materials should vary with the season.

FIG. 124. WHEELBARROW GRASS SEEDER.

(*a*) *Fertilizers to be used in connection with spring seeding* — When seeding in spring a selection of fertilizer materials furnishing nitrogen, as well as phosphoric acid and potash, should be made and the following is suggested: —

Nitrate of soda,	125 lbs.
Tankage,	200 "
Slag meal,	500 "
Muriate of potash, for light soils, or high-grade sulfate of potash for medium and heavy soils,	200 "

(*b*) *For fall seeding.*

Tankage,	200 lbs.
Slag meal,	800 "
Muriate or high-grade sulfate of potash (according to the soil),	200 "

In addition to the above, if the soil be very poor, it may be expedient to use about 100 pounds of nitrate of soda. In the spring following autumn

sowing it will often pay to use additional nitrate of soda at the rate of about 150 pounds to the acre.

518. *Top-dressing mowings* — Under an intensive system of farming the accumulated fertility of the soil, derived from application of the manures and fertilizers to crops occupying the land in rotation with the hay crop, will suffice for from one to two years, and further application of either manure or fertilizers might prove even harmful through causing the crop to lodge; but if the hay crop occupies the land for more than two years, top-dressing will generally prove useful. The selection of materials and the amount to

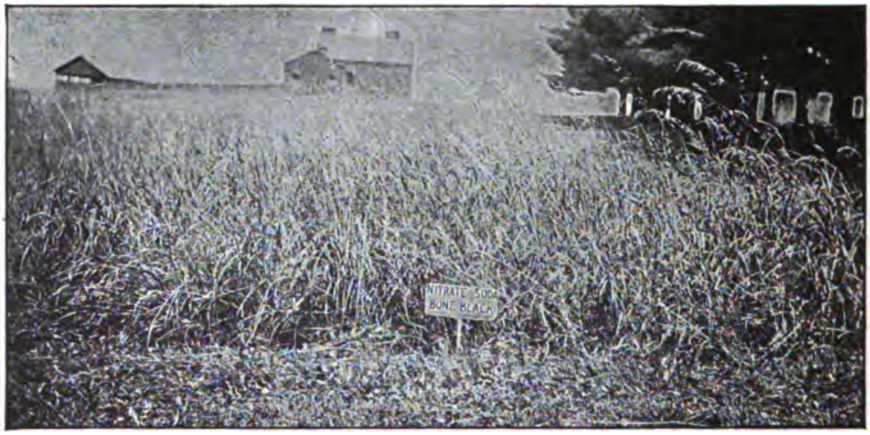


FIG. 125. Manured every year for thirteen years with nitrate of soda and dissolved boneblack. Seeded same as Figs. 126 and 127, but only grasses can grow, as there is no potash.

be used should vary according to the object which the farmer has in view. The growth of grasses is stimulated and promoted by the liberal use of manure and fertilizers furnishing nitrogen. The development of clovers, and other plants of the clover family, is greatly stimulated by the liberal use of materials which furnish phosphoric acid, lime, and potash, especially the latter. Whenever a mowing is allowed to lie for a number of years, it is found that the relative proportion of grasses and of clover and clover-like plants can be greatly modified by the system of manuring followed. The liberal use of materials furnishing nitrogen causes the grasses to take pos-

session of the ground, and the hay crop will be mainly composed of these. The liberal use of phosphates, potash, and lime has a marked effect in increasing the proportion of clovers, and the hay as a consequence becomes more nutritious, since clovers are far richer in food constituents than grasses. There is always a struggle in the meadow between the different plants for the possession of the ground. If by manuring we make the conditions

FIG. 126. Manured every year for thirteen years with dissolved boneblack and muriate of potash. Grasses can make but little growth, because they depend upon nitrogen ; clovers take nitrogen from the air and make good growth, as they find phosphate and potash in the soil.

more favorable to the grasses, they have an advantage, and grasses crowd out the clovers. The reverse of this statement is equally true. In proof of this statement, attention is called to the results of some experiments in Amherst in which the percentage of the different classes of plants produced under different manuring was determined as follows : —

Top-Dressed With:	Grasses. Per Cent.	Clovers. Per Cent.	Species, Other than Grasses and Clovers. Per Cent.
Nitrate of Soda	97.3	0.0	2.7
Dissolved Boneblack	90.9	0.0	9.1
Muriate of Potash	32.4	67.6	0.0
Nitrate of Soda and Muriate of Potash	52.6	47.4	0.0
Dissolved Boneblack and Muriate of Potash	11.3	88.7	0.0
Nitrate of Soda, Dissolved Boneblack, and Muriate of Potash	41.6	58.4	0.0

Experiments in various parts of the world, notably at Rothamstead, England, in meadows never known to have been plowed, have given similar results. On the grounds of the Massachusetts Agricultural College are several fields illustrating the varying effects in the relative proportion of grasses and clovers produced by different manuring in a very striking manner.

FIG. 127. Manured every year for thirteen years with nitrate of soda and muriate of potash. Here both grasses and clovers are found.

It must be evident, from the statements made and from examination of the above cuts, that the farmer may change the character of the herbage produced in his mowings almost at will, and therefore that in the selection of manures the result desired must be carefully considered.

(*a*) *Farmyard manure favorable to the growth of grasses* — Farmyard manure contains so large a proportion of nitrogen that its use proves highly favorable to the grasses, especially to timothy, and the farmer desiring to produce hay for sale may wisely employ such manure. If the quantity used is large the mowing will usually produce but little clover. On the grounds of the Massachusetts Agricultural College are plots of one-fourth acre each, some of which have been yearly manured with farmyard manure

at the rate of 6 cords per acre; others with 3 or 4 cords of similar manure and 125 pounds of muriate of potash per acre. The plots receiving manure and potash produce good crops with a large proportion of clover. The other plots produce somewhat larger crops, chiefly timothy. The cuts herewith presented show clearly the marked difference in the character of the growth under the two systems of manuring. The conclusion must be that,

FIG. 128. MOWING, first year; seeded with timothy, redtop, and clover. Manure, six cords per acre for eleven years; grasses most abundant.

if the farmer desires to produce hay of good nutritive character for his own use, and at the same time to enrich his soil in nitrogen through the growth of clover (430, b), he will wisely use comparatively little manure and supplement it with something which furnishes potash. The combined manure and potash costs some seven or eight dollars less per acre than the larger quantities of manure used in the experiments at Amherst. In view of the facts and principles which have been stated, the writer advises, where manure is available for top-dressing,—

1st. For the production of market hay, top-dressing in the fall: —

Manure alone at the rate of about 3-4 cords per acre.

2d. For the production of hay with a large proportion of clover for home use; top-dressing in the fall, per acre:

Manure,	2-3 cords.
Muriate of potash, (on light soils)	125 lbs. or
High-grade sulfate of potash on heavier soils)	125 "

(*b*) *Top-dressing with fertilizers for the production of market hay, chiefly timothy and redtop.*

Nitrate of soda,	150 lbs.
Tankage,	125 "
Acid phosphate,	50 "
Muriate or high-grade sulfate of potash (according to the soil),	50 "

These materials should be mixed and applied, for the latitude of central Massachusetts, from about April 20 to May 1.

FIG. 129. MOWING, first year: seeded as in Fig. 128; manure, three or four cords, and muriate of potash, 125 pounds per acre for eleven years; clover more abundant than in Fig. 128.

3d. For mowings in rotations including hoed crops, clover being desired. Per acre: —

Acid phosphate,	200 lbs.
Fine-ground bone,	400 "
Muriate or high-grade sulfate of potash,	150 "

These materials should be mixed and applied before the ground freezes in the fall.

4th. For permanent mowings, clover and clover-like plants being desired.

European experiments have demonstrated in a striking manner the very great value of a combination of phosphatic slag and potash salts for mowings of this character. Experiments in Germany and other Continental countries, as well as those in England and Scotland, have shown that, under

Fig. 130. Mowing, first year; seeded as in Fig. 128; fertilizers only; rich in potash for ten years; clover abundant.

this system of manuring, crops very satisfactory both in amount and quality are produced. The proportion of legumes is comparatively large; but while the first effect of the use of these fertilizers is to favor the growth of legumes, these, steadily enriching the soil in nitrogen, gradually improve the conditions for the grasses, which make use at last of a part of the nitrogen taken from the air by the legumes and made a part of their roots and stubble as these gradually decay. It is generally advised to use per acre about: —

Phosphatic slag,	500 lbs.
Muriate or high-grade sulfate of potash,*	140 "

*** In Germany kainite is often used, but here high-grade salts are cheaper (370, *b*).**

These materials are applied in the fall. Phosphatic slag in this country is now reasonable in price near the seaboard, and the European mixture of slag and muriate of potash is recommended. Farther inland the following mixture is recommended in its place:—

Ground South Carolina rock,	200	lbs.
Fine-ground bone,	400	"
Muriate or high-grade sulfate of potash,	140	"

These materials should be applied in the fall.

(*c*) *The use of manures and fertilizers in rotation.*

On the grounds of the Massachusetts Agricultural College, experiments have been continued eight years in the use in alternate years of three different manurings, viz., per acre:—

1st. Manure, 8 tons, applied in the fall at a cost of $15.

2d. Canada wood ashes, 1 ton, at a cost of $12.

3d. Fine-ground bone, 600 pounds.
Muriate of potash, 200 pounds,

applied at a cost of $12.

The average yield of hay in two crops for the years 1893 to 1909 has been 3 tons, 150 pounds per acre. This mowing was seeded in 1889. It is found that the cost of harvesting the hay crop from this field amounts to about $7 yearly per acre. The total yearly cost per acre, therefore, is $20, and for this amount we secure rather over three and one-fourth tons of hay. This affords a liberal margin for profit. It should be stated that the soil of the field where this experiment is under trial is a moderately heavy loam, rich in humus, tile-drained about fourteen years ago. On lighter soils the crops would undoubtely average less.

(*d*) *Top-dressing for rowen* — It is not usually the practice to apply any top-dressing between the first and second cut of grass, but it seems probable that in many instances a light application of nitrate of soda, immediately after the removal of the first crop, will produce a profitable increase in the rowen crop on all fields where grass predominates. Such a top-dressing where clover predominates would be entirely unnecessary. In

experiments on the grounds of the Massachusetts Agricultural College in 1900, the use of nitrate of soda as above indicated at the rate of 150 pounds to the acre gave an increase in the rowen crop on different plots at rates varying in most cases from about 800 to 1000 pounds per acre. The average increase was more than sufficient to cover the cost of the application of nitrate of soda. The effect varies widely in different years, chiefly with rain fall, and over a series of years has given but little profit.

519. *The hay harvest.* (*a*) *Season of cutting* — The time of cutting the hay crop should be determined by the degree of maturity of the plants.

FIG. 131. WOOD MOWER.

Both careful scientific experiments and practical experience indicate that hay of the best quality is obtained by cutting at about the time the grasses are in mid-bloom. Hay cut at this time, it is true, requires longer curing; but it is more tender and contains the more valuable nitrogen-containing food constituents in larger proportion; it is also more palatable and more digestible. There is much difference in the rapidity with which grasses deteriorate in value as hay after passing the flowering stage, but all become more woody, less palatable, and less digestible. Those peculiarly liable to become tough and woody have been pointed out in the descriptions which

have been given. The farmer may wisely allow grasses which are to be made into hay for horses to stand until somewhat more mature than when hay for cattle and sheep is desired. The horse feeder looks especially for hay which is bright, clean, free from dust, and cares less for its nutritive quality. Moreover, timothy is the favorite horse hay (as has been pointed out), and timothy is weakened by early cutting; for at that time the tuber, on the healthy condition of which its future growth depends, is not fully developed.

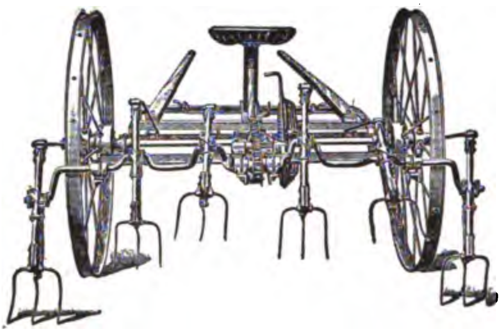


FIG. 132. HAY TEDDER.

(*b*) *Hay making machinery* — Most of the machines employed in the hay field are so well known that description seems unnecessary. The mowing machine, hay tedder, and hay rake are absolute necessities, and of each there are many kinds. The buyer should look for wearing qualities and durability first of all. There are many styles of each of these classes of

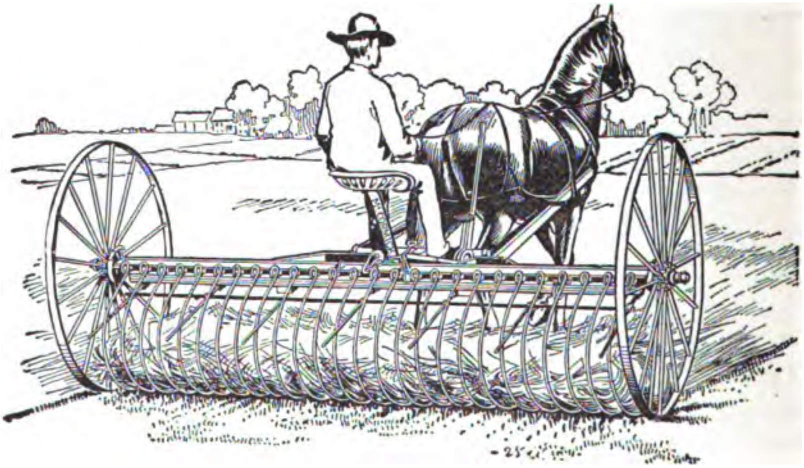


FIG. 133. SULKY RAKE.

machines which will do about equally good work. The hay tedder is somewhat less freely used by some of the best farmers at the present time than formerly, because of the amount of loss incident to the breaking off of the leaves and flowers, especially in the case of hay containing a large proportion of clover. Many farmers believe it is better to cure hay with as little

FIG. 134. SIDE-DELIVERY RAKE AT WORK.

of the violent shaking to which the hay tedder subjects it as possible. There is considerable difference in the motion of different hay-tedders in respect to the amount to which the hay is broken, and those with such motion as to break it least are preferable, provided they leave it light. The ordinary sulky hay rake will prove most valuable under the conditions existing on most farms, but where the fields are large and smooth the side delivery rake used in combination with the hay loader will be found highly useful.

By the use of the side-delivery rake the hay is left in better condition to be picked up by the loader than by the ordinary sulky rakes. The side-delivery rake, moreover, not scratching the ground as do the ordinary sulky rakes, gathers the hay more free from dust.

If the mows in the barn must be built any considerable distance above the floor on to which the wagons drive with the hay, a horse fork will also be essential to the most economical work. There are many types. The harpoon fork, either single or double, is well adapted to handling coarse hay; while one of the grapple forks is more satisfactory with fine hay.

520. *Selection of grasses for pastures* — The points to be taken into consideration in selecting grasses for pastures are the same as those which must be considered in selecting for mowings (513) with one exception, viz., for mowings the grasses put together should all flower at the same time; for pastures considerable difference in time of flowering is desirable. The reasons are self-evident. We need in the pasture a succession of grasses, some which start very early in the spring, while at the other extreme those which continue growth until very late and which are comparatively little injured by frosts are desirable. The number of species which should be included in a pasture is usually greater than it will be worth while to put into a mowing.

MIXTURES FOR PERMANENT PASTURE.

	Light Soils. Pounds.	Medium Soils. Pounds.	Heavy Soils. Pounds.
Timothy	3	4	3
Redtop	4	2	5
Orchard grass	8	8	4
Meadow fescue	4	4	4
Hard fescue,	..	..	2
Tall fescue	2	2	4
Kentucky blue grass	4	4	5
Rough-stalked meadow grass	..	..	4
Italian rye grass	3	4	2
Tall oat grass	..	4	..
Meadow foxtail	2	3	3
Yellow oat grass	3	..	..
Sweet vernal	2	..	..
White clover	4	4	4
Alsike clover	1	2	3
Pea-vine clover	2	..	2

Professor Fletcher of the Agricultural College of Ontario, who has made a special study of grasses, recommends for combined mowing and pasture, the former for two years, the latter for three, the following mixture: —

Timothy,	6 lbs.
Meadow fescue,	4 "
Orchard grass,	2 "
Kentucky blue grass,	1 "
Medium red clover,	2 "
Alsike clover,	2 "
White clover,	2 "
Alfalfa,	2 "

This is much lighter seeding than the writer usually advises, but may be sufficient on the comparatively rich and virgin soils of the region for which it is intended. The alfalfa would probably not prove hardy near the seaboard, but on fields which are thoroughly drained, in localities with abundant snowfall, it may prove of value.

FIG. 135. HAY LOADER AT WORK; beginning.

521. *Seeding pastures* — As is well known, the pastures on most farms in the region under consideration usually receive little attention. In few cases in this section have the pastures been artificially seeded. The pasture as a rule is rough, and in many cases partly grown up to trees and shrubs, ferns, hardhack, etc. To sow expensive mixtures of grass seeds in such pastures would clearly be inexpedient; but many of our best farmers are no longer satisfied with pastures of this description. It is recognized that, if the dairy cow is to give her best yield, she must not be forced to hunt all

day amid rocks and bushes for the food she needs. For the best results the pasture should be good enough so that the cow will find the needed food within a few hours, and have abundant time for rest and chewing the cud. Rocks, bushes, ferns, hardhack, etc., should be removed, the pasture should be cleared, and when cleared it will pay to sow seeds of the best grasses. The time and manner of sowing may be the same as in the case of mowings.

FIG. 136. HAY LOADER AT WORK; load nearly made.

522. *Manuring pasture land*—Up to the present time, in the great majority of instances, the farmers of the Northeastern states have not made it a practice to apply either manure or fertilizers to their pastures. As a consequence we find pasture lands in very many localities greatly exhausted, producing little and very inferior herbage, the surface largely covered with moss. It can hardly be expected that the application of farmyard manures to pastures, which in many cases lie at a distance from the farmstead, will be profitable; but without doubt it will pay to apply suitably selected fertilizers to pasture lands which are not excessively rough, where the surface is not too steep, or occupied to too great an extent by shrubs, ferns, etc. On the well cleared, smoother pastures such fertilizer mixtures may wisely be

employed as have been recommended in the case of permanent mowings, where clover-like plants are desired (517). To the pasture, however, the quantity of materials applied should be somewhat less than in the case of mowings. The use of wood ashes alone would doubtless in many instances greatly improve our pastures.

LXXIII—SUB-CLASS II. ANNUAL FORAGE CROPS: FOR HAY, SOILING, FOLDING, OR ENSILAGE.

523. *The use of annual forage crops* — Under the more intensive system of agriculture of recent years, increased attention is paid to the production of annual forage crops, which, according to circumstances and kind, are cut and made into hay to supplement a threatened shortage from the regular mowings; cut and fed green (soiling); or pastured, usually by confining the animals successively to small portions of the field (folding); or cut and put into the silo (ensilage). The number of crops used for these various purposes is large. The farmer of to-day has a wide range of choice, and from the list which will be spoken of will have no difficulty in making a selection which will suit the special conditions under which he works. The crops which are used for the purposes just designated are many of them members of the grass family; a considerable number belong to the clover family, and a few to the turnip family. These crops are best considered under the classes which have been named in paragraph 448.

FIG. 137. GRAPPLE AND DOUBLE HARPOON HAY FORKS.

524. *Small grains* — All of the common small grains of this country are used for the purposes under consideration, though their most important use is for soiling or folding. They make less desirable hay than the perennial grasses and are inferior for ensilage to corn. Rye and oats are the grains which are most often used as forage crops in the Northeastern states.

(*a*) *Rye* — Rye is grown chiefly because it is ready to feed earlier than any other crop. The forage is inferior in quality and is not relished by

cattle. Indeed, it will scarcely be eaten by well fed animals after it is fully headed out. Rye is adapted to medium and light soils. It may be pastured both in autumn and spring. The seed is sown broadcast or with a drill at the rate of from about 1½ to 2 bushels per acre. It may be sown from about the first of September to the middle of October, for the purpose of furnishing a succession of feed.

(*b*) *Oats* — Oats are far more palatable than rye and are quite extensively used as a soiling crop. Oat hay is more palatable than hay made from any other of the grains under consideration. Oats will thrive upon a great variety of soils but do their best on the medium to heavy loams which incline to be cool and retentive of moisture. Oats for fodder should be sown on two or three different dates, at intervals of about ten days, to give a succession. The quantity of seed required varies with the soil from about 2 to 3½ bushels per acre if sown broadcast; 1½ to 2 bushels if put in with the drill.

(*c*) *Wheat* — Wheat is not very generally used as a forage crop but has qualities which render it desirable under certain circumstances. It is more palatable to cattle than rye and keeps in condition for feeding longer. It is the winter varieties which are likely to prove most useful. These may be sown throughout about the same season as winter rye and the crop will be ready to feed a little later than rye sown on the same date. It is believed that it will generally be preferable to plan to have wheat for soiling follow rye, rather than to sow successions of rye, on account of the greater palatability of the former grain. Wheat does best upon the medium to heavy loams. Its chief use will be for soiling or pasturage. It does not make good hay and cannot be recommended for ensilage. The quantity of seed required is from about 1¼ to 2 bushels per acre.

(*d*) *Barley* — Barley is suited to the medium to light soils, but will not thrive on soils quite so light as rye. On account of its long hairs barley is less relished by stock than oats or wheat. In some sections of the country it is much grown for hay but in the North Atlantic states its chief use is as a soiling crop for late autumn feeding. It endures autumnal frosts better than oats, and is less liable to rust in the autumn than oats. It may be sown

from about July 25th to August 10th for autumn feeding. The quantity of seed required is from about 1½ to 2 bushels per acre.

(*e*) All of the grains under consideration are often sown together with some of the legumes, especially field peas, or vetches; and forage, whether for soiling, hay, or ensilage, consisting of a mixture of either vetches or peas with grain is more palatable and more nutritious than grain alone. The best combinations and the quantities of seed required will be considered under vetches and peas.

1. 2. 3.

FIG. 138. MILLETS, SINGLE PLANTS: 1, Foxtail; 2, Barnyard; 3, Broom Corn.

(*f*) *Manures* — The manures needed for the crops under consideration will be in general similar to those which these crops need when grown for grain, and the especial consideration of this branch of the subject will come under grains. The only difference which it is believed should be made when these crops are grown for forage is to use somewhat more freely materials furnishing both nitrogen and potash. Fertilizers supplying these elements are likely to increase the proportional development of the stem and leaf.

525. *Millets* — There are many distinct kinds of millets. Under this general name are indeed included plants so widely different that botanists place them under distinct genera and species. The millets are an exceedingly useful class of plants, being employed most largely as hay crops. In many cases the farmer does not plan for them at the opening of the season, but if he finds himself likely to have insufficient hay from his mowings he is very likely (and this is wise) to sow millets to help fill the barn. A few of the millets are valuble for soiling and they are sometimes pastured. A few of them also have been used for ensilage, but the use of millets for this pur-

pose must, it is believed, in general be subsidiary to their main use, which is as hay crops. Many of the millets mature within a comparatively short time. This renders them especially suited to the main purpose which has been indicated. They are all tender crops, injured by frosts. They should not be sown until soil and weather are warm. If sown too early, weeds are likely to outgrow them, as their progress at first would be exceedingly slow.

(*a*) *Foxtail millets* (*Chætochloa Italica*) — Millets belonging to this class are the most generally known and most widely cultivated in the North-eastern states. There are numerous varieties under the following names: Common, German or Golden, Golden Wonder, Siberian, Hungarian, and Japanese Foxtail. Among these Hungarian is generally best known and is perhaps the most valuable. The millets of this class are used in this country almost exclusively as hay crops, though some of them are grown for seed, which is used for birds and to some extent for the larger domestic fowls. The leading characteristics of the different varieties may be briefly summarized as follows: —

Common — Moderately coarse, growing about 3½ to 4 feet in height on ordinary soils, drooping and moderately heavy heads, stems inclining to become rather tough and woody soon after flowering. It should be cut for hay soon after it begins to head. When grown as a hay crop, 2 or 3 pecks of seed per acre are required; when grown for seed, 1 peck.

German or Golden millet — This is simply a large and comparatively coarse variety of the common millet. It must be cut early to make good hay. Unless sown thickly it becomes too coarse and woody.

Golden Wonder — This is a variety closely allied to the common millet but with very long, drooping heads. It is a larger and coarser plant and unless sown thickly and cut early does not make hay of good quality.

Siberian — This variety has been comparatively recently introduced into the United States and is not much known. It is finer in the stem than the German and the Golden Wonder. It makes a quick growth.

Hungarian—Botanists class this as *Chætochloa Italica*, variety *Germanica*. It differs from the common millet somewhat more than the others which

have been named but it is still closely allied thereto. It is finer in the stem and has a much smaller head than that of common millet, and the head is nearly erect. Hungarian grass matures within a very short time and on this account, as well as because of its fineness, it is one of the most valuable of the hay millets. It is often ready to cut within about sixty days from the time of sowing. From 2 to 3 pecks of seed to the acre are required when grown as a hay crop.

FIG. 139. JAPANESE FOXTAIL MILLET.
By courtesy of Hatch Experiment Station.

Japanese Foxtail—This variety of the species to which the common millet belongs has been cultivated in the Orient as a seed crop from time immemorial. It has been carefully selected with reference to large seed production. The stems are coarse and woody, the heads very large and drooping. When sown thinly on soils of ordinary fertility, heads a foot in length and one inch in diameter are frequently produced. This millet appears to be rather too coarse for hay, though if sown thickly it might be modified somewhat in this respect. It is, however, much more susceptible

to injury from drouth than Hungarian grass, and moreover it requires a much longer season to mature. It is not recommended as a hay crop. Hungarian grass is superior. This millet should be put upon soils somewhat more retentive of moisture than those suited to the other millets of this class.

(*b*) *Broom corn millets* (*Panicum miliaceum*) — The millets belonging to this class take their common name, for the reason that the heads, though smaller, are in general shape and appearance somewhat similar to the heads of broom corn. Another name sometimes used to designate the class is panicle millets. All of these millets have comparatively woody and tough stems and the plant is somewhat hairy. They have greater capacity to resist drouth than most of the millets of the other classes. The hairiness of the plant renders millets of this class somewhat less attractive to animals than others. There are many varieties of this class. Some of the more common and valuable are known under the following names: French (of which there are two subvarieties, one with light colored seed, the other with reddish seeds), hog millet, Japanese broom corn (of which there are many varieties, both white and red seeded). As grown on the grounds of the Massachusetts Agricultural College, the different varieties which have been named have shown the following characteristics: —

French millet — All the French millets tried have grown rapidly, have attained a height of from about 3½ to 4 feet, and have given a relatively small yield. They are not likely to prove valuable in the Northeastern states.

Hog millet — This showed characteristics very similar to those of the French millets, maturing quickly, but it reached a height of from only 3 to 3½ feet and gave an even smaller yield than the French millets.

Japanese broom corn millet — This has been grown for a considerable number of years and usually gives heavy yields. It requires from two to three weeks longer to reach maturity than the French or the hog millet, but grows to a considerably greater height, on good soils about 6 feet, and gives far heavier yields. It is, however, rather coarse and woody as well as hairy; and the writer does not recommend it as a crop either for soiling or for hay. When sown in drills about 1 foot apart, the amount of seed re-

quired is 5 to 6 quarts. There is not much difference in the general characteristics of the white and red seeded varieties of the Japanese broom corn millet.

(*c*) *Barnyard millets* (*Panicum crus-galli*) — Millets of this class are of very recent introduction to the agriculture of the Northeastern states. The most valuable variety was imported from Japan by the writer ; and this

FIG. 140. JAPANESE BROOM CORN MILLET
By courtesy of Hatch Experiment Station.

variety is often known simply as Japanese millet, it having taken this name because it has proved much the most valuable of the different Japanese millets which have been introduced.

Japanese barnyard millet has been cultivated in the Orient from very ancient times as a seed crop, the seed being used as human food. It belongs to the same species as the common barnyard grass of our fields but in the habit of growth and particularly in the shape of the heads it differs from that grass in a marked degree. The growth is very erect, stems often quite coarse but remarkably succulent and tender in texture. The height

reached on suitable soils is from 6 to 7 feet. The whole plant is very leafy and when fed green proves exceedingly palatable to all classes of animals, and has given excellent results when used for soiling milch cows. It is usually consumed with less waste than green corn fodder and the yield of milk is equally satisfactory. The yield on good soils is heavy, not infrequently amounting to 20 tons green weight. The crop is used to some extent for ensilage but cannot be handled as conveniently as corn without

FIG. 141. JAPANESE BARNYARD MILLET.
By courtesy of Hatch Experiment Station.

special machinery. The grain reapers made somewhat stronger might without doubt cut and bind this millet, and handled in this way the cost of putting it into the silo will probably not be greater than is the cost of handling corn. This millet makes good hay if well cured but it requires long curing and good weather on account of its extreme succulence. It is not recommended as a hay crop. Its chief value will be as a soiling crop, for which use it is a decided acquisition to those farmers who believe in intensive agriculture. It is not a millet for poor soils. It is best suited to moderately moist soils, of good retentive quality, and containing considerable

humus. It is very impatient of drouth. On soils of good quality it stools more abundantly than any other millet, and on this account it should not be sown too thickly. From 10 to 12 quarts of seed to the acre is sufficient when the millet is grown as a forage crop, provided the millet is sown in good season. If put in late more seed should be used.

The Indians of the Southwest have grown a variety of barnyard millet for many years under the name of "Ankee" grass. This grass they cultivate for its seed. It has been given a trial in Massachusetts as a forage crop but proves far less satisfactory for that purpose than the Japanese variety in that state. It is reported to withstand drouth far better than does the Japanese variety.

(*d*) *Cat-tail millets* (*Pennisetum spicatum*) — The millets which belong to this class take the common name, cat-tail millet, on account of the resemblance of the spike or head to the common cat o'nine tails in our marshes. This spike may vary in length from about 6 to 12 inches. All the millets in this class are coarse, tall-growing plants with stems very hard, tough, and woody when ripe. All require warm soil and hot weather to do their best and must have a long season in order to reach maturity. They are of very slow growth at first and must usually be sown in drills and given some cultivation, unless the soil has previously been very thoroughly freed from weeds and weed seeds. None of these millets, it is believed, will mature in the climate of central Massachusetts. In coarseness and general appearance they resemble the corn plant almost more than they do the millets of the other classes, although the stems are hollow and jointed as are the stems of the other millets. They have a habit of stooling abundantly so that comparatively little seed is required. If cut some time before they reach maturity, the millets of this class are fairly palatable, and, with appropriate soil and climatic conditions, they may prove valuable either for soiling or for ensilage. It is not the belief of the writer that these millets will usually prove preferable to corn for either of these uses. In comparative trials on the grounds of the Massachusetts Agricultural College, corn produced more fodder at less cost, chiefly because of its more rapid early growth. Among the common names applied to millets in this class are

the following: Pearl millet, Mand's Wonder Forage Crop, Brazilian millet, etc.

Pearl millet requires a much longer season than is found in the latitude of central Massachusetts.

It is claimed that *Mand's Wonder*, which in the opinion of the writer is without doubt the same species, but which has been called by the introducer *Pencilaria zeaoides*, will mature in a considerably shorter season. This variety has yet to be tried in the Northeastern states.

FIG. 142. PEARL MILLET.

The name *Brazilian* millet appears to be applied to what is simply a strain of the common pearl millet, the new name being apparently the only reason for the far higher price charged for the seed. It is not believed that any of these millets can prove valuable for dry fodder, as they are likely to become tough.

(*e*) *Soils and manures for millets* — The millets in general, with the exception of the Japanese barnyard, whose requirements have been specially pointed out, will do their best on the medium to light loams. For large crops a high condition of fertility is required. Since millets are so often grown as catch crops, and since plans will not have been laid any considerable time in advance of seeding, it is in general necessary to use manures or fertilizers containing a large proportion of available plant food. If manures are selected, they should be fine and partially rotted. If fertilizers are selected, such materials as might be used for corn may wisely be employed, as the millets in their feeding habits and plant-food requirements much more resemble corn than they do the ordinary grasses. This is undoubtedly due to the fact that they

make most of their growth at the same season with corn, *i. e.*, in the hot summer weather. This peculiarity enables the millets like corn to depend more upon soil nitrogen than can the ordinary grasses of our mowings. For information as to selection of materials the reader is referred to corn (535, *a*).

526. *Indian corn and teosinte* — These crops find their chief use as forage for soiling and ensilage, though both are sometimes cured and fed dry. Both the experience of practical farmers and the careful scientific experiments conducted in our various stations have conclusively established the fact that these crops, particularly corn, can be more profitably used as silage than in the form of dry fodder. Both in silage and in the process of curing crops like Indian corn there is some loss of food value. Neither the silage nor the cured fodder made from green corn is equal in food value to the green fodder. The loss is usually about 10 or 12 per cent., and is not widely different under the best conditions for the two processes. Silage, however, is far more palatable than dry fodder and is consumed with less waste, so that the milk or other dairy products produced from feeding corn in the form of silage grown on a given area has been found to exceed that produced from feeding the dried fodder grown on an equal area by about 10 to 12 per cent.

(*a*) *Indian corn* (*Zea mays*) — Everything considered, Indian corn must be regarded as our most valuable forage crop. Could we have but one of the various crops which are under consideration, there is no doubt that corn should be the one selected. It thrives throughout all the North-eastern states on a wide variety of soils and gives large yields of very palatable forage. There are several distinct classes and many varieties. Among the classes of corn which have a value as forage crops are the sweet corns, flint corns, and dent corns. The sweet corns are in high favor for feeding green as the green forage is somewhat more palatable and nutritious than that produced by varieties belonging to the other classes. The only consideration unfavorable to the more general use of sweet corn for forage is the fact that the seed is more costly and less certain to germinate than that of varieties of the other classes. Well cured sweet corn seed may not

be inferior to seed of the other classes; but sweet corn seed is difficult to cure, and there is unfortunately considerable poor seed offered in our markets. This consideration deters many from selecting any of the sweet varieties for forage. The sweet corns dried are more palatable and more nutritious than varieties of the other classes, but silage from such varieties is not in general favor, as it is likely to contain more acid than silage made from varieties of either of the other classes. For forage the larger and later varieties of sweet corn are usually most valuable.

Flint corns, in which class there is a great variation in the range of season required and in the size attained by the plants, and therefore in the productive capacity, are often grown for forage, whether for soiling or for ensilage. There appears to be no decided difference in nutritive value between the flint and the dent classes of corn. In such careful trials as have been made in localities where dent varieties flourish, these varieties have usually proved somewhat superior to flint varieties in productive capacity. Flint varieties, however, are in general somewhat less fastidious as to soil and climatic conditions than are dent varieties, and where the season is short and the climate comparatively cool varieties of this class should be selected. The stalks of flint varieties are as a rule less coarse than those of dent varieties. The plants, moreover, incline to sucker more. On this account some prefer flint varieties when the fodder is to be cured, believing that the finer stalks are more palatable. It is, however, more difficult to make corn which has slender stalks and which has suckered freely stand in stooks, and for this reason such fodder often cures less perfectly than the coarser product of the dent corns.

Dent corns. Many of the characteristics of the varieties of corn included in this class have been stated in the comparisons made between the flint and dent varieties. Although there are varieties of dent corn sufficiently early for the latitude of central Massachusetts, on favorable soils the varieties in this class in general require a relatively long season. The plants grow to great height with large stalks, with few if any suckers. Dent varieties are in general preferred to flint for ensilage. They are likely to give somewhat larger yields.

Varieties — A few varieties, known to be suited to the conditions prevailing in the central portion of New England, will be named : —

Sweet corn : Stowell's Evergreen.

Flint corn : Sanborn, Longfellow, Rural Thoroughbred.

Dent corn : Sibley's Pride of the North, Leaming Field.

Where more than one variety has been named in a class, the names are placed in the order of earliness.

(*b*) *Teosinte* (*Reana luxurians*) — Teosinte closely resembles corn. The general habit of the plant is the same, although it suckers much more freely than any variety of corn, and the suckers many of them reach about the same size as the main stem and mature at about the same time. Teosinte has the pithy stem of the corn, leaves like corn, and produces a large number of very small, fragile ears, several at each of some four or five joints at and near the middle of the plant. These ears have no true cob, the kernels being borne on a center axis, which is very slender and fragile. The plants of teosinte are terminated with a tassel like that of corn. Teosinte is tropical in origin and requires a long season and a warm soil. It will not mature in central Massachusetts. While, under some circumstances, it may prove of value for green forage, having about the same nutritive qualities and texture as corn, it is not believed that conditions will often be found under which it will be expedient to use this crop in place of corn. Its growth at first is much more slow and it is much more susceptible to injury through excess of rain or a low range of temperature.

(*c*) *Soil and manures for Indian corn and teosinte* — When grown for forage, these crops require the same treatment, as regards soil and manure, as does corn as a grain crop, with the possible exception that it will pay to use either manures or fertilizers somewhat more freely, as a heavy growth of forage is of course desirable. Soils and manures will be discussed in that section where corn as a grain crop is considered (535, *a*).

(*d*) *Manner of planting* — When grown for forage, Indian corn should usually be planted in rows, the distance between which should vary with the variety, the usual range being about 3 to 3½ feet. The work can be most economically performed by machine. The quantity of seed required to the

acre varies with the variety, but is usually about 12 to 16 quarts. Teosinte also should be planted in drills, the distance between which should be about 3½ feet. The quantity of seed required is much less than it takes of corn, on account of its smaller size and the extent to which it stools. A few pounds of seed only will suffice for an acre. The season of planting in the Northeastern states will vary from about May 1 to June 10, according to location, soil, and variety.

FIG. 143. EARLY AMBER SORGHUM. *After Shaw.*
By courtesy of Minnesota University Experiment Farm.

527. *Sorghum and sorghum-like plants* — In many respects the crops included in this class resemble the corn plant in their development. The stems are solid like those of corn, but the seed is produced in a panicle which develops at the top, as in the case of the common grasses of our mowings. The crops of this class are all of them warm weather crops. They have a reputation of enduring drouth far better than corn, and it is this consideration chiefly which sometimes leads farmers to prefer one of these crops to the Indian corn. Many of them sucker or stool more freely than corn and

the stalks are consequently likely to be finer. In the case of the sorghums, the forage is very sweet and is highly relished by stock. Without exception the crops of this class grow very slowly at first. There is a considerable period during which they appear to be making root, and when the top makes little progress. This peculiarity renders the culture of these crops more troublesome and more costly than that of corn, as weeds are likely to outgrow them. In productive capacity they do not exceed corn, under the conditions prevailing in the Northeastern states; and in that locality there can be few circumstances under which they should be grown as forage crops in preference to Indian corn. They are suited to the same uses, viz., soiling and ensilage. There is a considerable number of crops in this class:

1st. *Varieties of Sorghum vulgare* — Sorghum, of which there are a number of varieties, Milo maize, and Kaffir corn.

2d. *Varieties of Andropogon sorghum* — Dhcurra and Jerusalem corn.

(*a*) *Sorghum* (*Sorghum vulgare var. saccharatum*) — Under this name are designated such varieties of the species as are used for the manufacture of molasses or sugar, as well as for forage. The different varieties require widely varying length of season for maturity, but there are several which can be counted upon to mature in most parts of the district under consideration; among these the Early Amber is one of the best known. On warm soils, in a fair condition of fertility, this variety may be counted upon to reach a height of from about 8 to 10 feet and will give good yields.

(*b*) *Kaffir corn* (*Sorghum vulgare*) — This belongs to a class of sorghums which are often collectively spoken of as non-saccharine, *i. e.*, they are not sweet enough to be profitably used for the manufacture of sugar. Kaffir corn is undoubtedly able to endure far more severe drouths, and to give profitable crops in much drier climates and soils than those required for corn, and it is now considerably cultivated in the semi-arid West, both for seed and for forage. It is not as tall in its habit of growth as sorghum, and in the Northeastern states is not likely to prove of as much value for forage as the ordinary sorghum.

(*c*) *Milo maize* (*Sorghum vulgare*) — This is another non-saccharine

sorghum, but, except for being less sweet, it has much the same general characteristics as the early amber sorghum.

(*d*) *Dhourra* (*Andropogon sorghum*) — This requires about the same length of season as Kaffir corn. It produces a large amount of seed and is less valuable for forage than sorghum.

(*e*) *Jerusalem corn* (*Andropogon sorghum*) — This has the same general habit of growth as dhourra and is somewhat less leafy. Both this and dhourra grow even more slowly then sorghum, and must, therefore, have even less value than that plant.

(*f*) *Soils and manures for the crops of this class* — The warmer cōrn soils should be selected for all the crops of this class. It is highly necessary, if their culture is to be undertaken, that previous crops shall be of such character and receive such culture as will leave the land clean. The manurial requirements of the crop are similar to those of corn (535, *a*).

FIG. 144. KAFFIR CORN.

(*g*) *Manner of planting* — The seeds of all the crops of this class are comparatively small, and can be economically planted only by machine. The season of planting is the same as for corn. They should be put in drills. In the West, where the grain drill is found upon every farm, these crops are often put in with that machine. The practice recommended by Shaw consists in sowing in double rows, the distance between which is the same as between the tubes of a grain drill, these double rows being separated by a sufficient interval (usually

from 3 to 3½ feet) to allow free intertillage. The seed is readily planted in this way by stopping a portion of the tubes of the drill. The seeds can be successfully planted by many of the corn planters by a slight change in the dropping attachments. It requires but a very few pounds of seed per acre.

528. *Legumes* — There is a considerable number of annual plants coming under this group which are specially valuable under suitable conditions as forage crops. It will be remembered that all the plants of this family can take most of the nitrogen needed from the air. This makes it possible not only to produce them at much less cost for manures than other crops, but at the same time to enrich the soil in nitrogen (133,*b*). This consideration alone should lead to the more extensive cultivation of forage crops belonging to this family. There is, however, yet one other respect in which they are much superior to forage crops belonging to other families. They are far richer in flesh-forming constituents which must enter largely into milk. These are the constituents for which most farmers spend much money in the purchase of concentrated foods, such as linseed, gluten, and cottonseed meals. The necessary expenditure for foods of this class can be much decreased by the more general production of forage crops belonging to the great clover family. The most important of the annual forage crops will be briefly considered.

(*a*) *Crimson clover* (*Trifolium incarnatum*) — Much like the other clovers in many respects, this clover is unfitted for mowings because strictly an annual requiring to be sown yearly. Its chief use must be in furnishing a crop for early feeding. It is ready for use several weeks earlier than the other clovers. It is adapted either for soiling or for hay, but should be cut as soon as it comes into flower, as thereafter it rapidly becomes tough and woody. Moreover, if cut just as soon as it begins to flower, it will give a second and even a third cut during the season ; but if cutting be delayed until the plant has been in flower for some time the roots will die. Still further, the heads in the mature clover are thickly covered with long hairs which have sometimes been found to produce digestive disturbances. This clover is rather liable to injury in early spring, in severe climates, and it is

not believed that it can generally be grown with success (save in regions having abundant snow, which lies upon the ground until late in the spring) north of New Jersey.

Soils and manures — This clover requires perfect drainage and does best on light soils. It endures drouth and heat better than the other clovers. The use of manures and fertilizers should be guided by the same considerations as those to which attention has been called in discussing the manuring of mowings where clovers are abundant (518, *c*).

Time and manner of sowing — In the Northern states, crimson clover should be sown in July or early in August. About 20 pounds of seed per acre are needed. Oats, at the rate of from 1½ to 2 bushels per acre, may be sown with it to give winter protection where needed. In localities where winter protection is not needed, this clover may be sown in the corn at the time of the last cultivation (516, *b*).

1. 2. 3. 3.

FIG. 145. FIELD PEA. Manure applied: 1, nothing; 2, nitrate of soda; 3, phosphate and potash; 4, nitrate of soda, phosphate, and potash; showing that this crop can be grown without nitrogen manuring, if phosphate and potash are supplied.

(*b*) *Field pea* (*Pisum arvense*) — This is one of the most widely used, and certainly one of the most valuable, of the annual forage crops in this group. It has capacity for large production; and the forage, whether green or cured, is highly palatable and nutritious. The crop is especially valuable for soiling milch cows, and when cured is peculiarly adapted for sheep. If sown alone the vines, not finding support, fall to the ground. This interferes with their development and the forage produced is of inferior quality. Field peas, therefore, are almost invariably sown in combination with a crop on which the vines can climb. The most common mixture is oats and peas. This mixture is valuable for soiling, for hay, and for folding. There are a number of varieties of field peas, but none appears to be distinctly superior to the common Canada field pea.

Soil and manures — Peas do best upon deep, heavy, retentive loams which incline to be cold; and they are best suited, it may be remarked, to cool climates. They should be manured about as are clovers.

Time and manner of sowing — Peas should be planted in very early spring for the largest yields. They are sown both broadcast and in drills. A good method is to sow them upon the rough furrow and work in with a disc harrow. Then, after three or four days, sow the oats and cover with a spike-tooth harrow. The field should then, in most cases, be rolled. The reasons why this method is advisable are that peas require deeper covering than oats and are, therefore, slower in germinating. The quantity of seed to be used under average conditions is from about 1 to 1½ bushels of peas, and 1½ to 2 bushels of oats.

(*c*) *Vetch* — There are a number of distinct species of vetch, all of which have some special value as forage crops; many of them are perennial and are of value in permanent mowings and pastures. The so-called "sand or hairy" vetch (*Vicia villosa*) has been highly praised in some quarters, but, while it might be preferable to the ordinary vetch for light soils, it is not believed that it will generally prove equally satisfactory.

Common vetch (*Vicia sativa*) — The vetch has many of the characteristics of the field pea, but has a more slender and finer stem, and a more delicate habit of growth. There are two classes of vetches, spring and winter. It is not believed that the spring vetch is likely to prove generally useful in the Northeastern states. If a spring-sown crop is needed, the pea will generally be more satisfactory. The winter vetch,* however, is distinctly valuable for sowing with winter grains, for which purpose either rye or wheat is best. The mixed forage is valuable for soiling especially, to a less degree for hay.

Soil and manures — Vetch is suited to soils of the same kind as those best for peas, and should be manured in about the same way. Farmers are especially cautioned against sowing vetches in soils that incline to be dry. They do not make a satisfactory crop unless they have abundant moisture.

---

* See Fig. 80, p. 360.

Time and manner of sowing — In the somewhat trying climate of the Northeastern states, winter vetch needs to be sown rather early, in order to become sufficiently rooted to pass through the winter safely. From about the 25th of August to the 10th of September will be the usual range in time for successful sowing of the winter vetch. It is sown either broadcast or with a grain drill, and in combination with grain. From about 1 to 1¼ bushels of vetch and 1¼ to 1½ bushels of either wheat or rye will usually be found satisfactory.


FIG. 146. SOY BEAN.

(*d*) *Soy bean* (*Glycine hispida*) — This crop is of comparatively recent introduction in the agriculture of the United States; and it is not yet generally well known, though it has long been cultivated in the Orient as a crop for human food. In this country, its chief use is as a forage crop. It is well suited for soiling or for ensilage. It does not make very satisfactory hay. In some parts of the West, it is used as a pasture crop for hogs and sheep, and the results are said to be highly satisfactory. There are many varieties; some requiring but a very short season to reach maturity, others requiring so long a season that they will hardly come into flower in central Massachusetts. In some instances, these very late varieties have been planted for forage in the Northern states, a large growth of vine being considered desirable. Bulk in a forage crop should not be confused with value. A crop which is reasonably near maturity has a greater food value, pound for pound, in many cases than the same crop immature. This is certainly true of the soy bean. Among the varieties which prove most valua-

ble in the Northeastern states for forage, the medium green is one of the best. This crop will mature in similar soils in about the same length of season required by the "Longfellow" or "Sibley's Pride of the North" corn. It ripens its seed in the latitude of central Massachusetts. On good soils, it will give a yield of from 10 to 12 tons green weight to the acre, under favorable soil and climatic conditions. The forage is quite palatable to cows. It should be used from the time of flowering to the period when the pods are from one-half to three-fourths grown. Later than this, the stems become too woody to be relished. The crop has been very successfully used in ensilage, but must be put in alternate layers with about double the quantity of some forage less rich than itself, such as corn. If put in alone, the silage becomes strong and disagreeable in flavor.

FIG. 147. LEAF AND PODS OF THE COW PEA. (*Vigna catjang*).

Soil and manures — This bean will do its best upon good corn land. It should be manured in about the same manner as clover.

Time and manner of planting — This bean should be planted at about the same time as corn. Where both crops are grown, it will be best to put it in immediately after finishing planting the corn. It can be successfully

put in with any of the corn planters. It should be sown in drills about 2½ feet apart. About ½ bushel of seed to the acre is ordinarily sufficient.

(*e*) *Cow pea* (*Vigna catjang*) — This crop has long been extensively cultivated in the South, where it is one of the most important forage crops, being fed green as well as made into hay. Its introduction into the North is comparatively recent, and is due in part to the higher appreciation of crops belonging to the clover family in general, and in part to the fact that varieties requiring a comparatively short season have been produced. The cow pea is eminently a hot weather crop, and only the earliest kinds will become sufficiently mature to develop their full feeding value in the Northern states. The Black and the Blackeye are among the earliest. The forage is fairly palatable and highly nutritious, and this pea has been reported upon favorably as a soiling crop for milch cows. It may also be used for ensilage in the manner indicated for the soy bean. Its productive capacity is about the same as that of the soy bean. Its capacity to endure drouth is greater.

Soils and manures — The cow pea is suited to the lighter and warmer soils. It should be manured like clover. It should be planted as directed for the soy bean.

(*f*) *The flat pea* (*Lathyrus sylvestris*) — This crop has been brought to the attention of the American farmers within the past ten or twelve years. It has been carefully tried in many experiment stations and by some private farmers, but is not generally liked. It is a true perennial. When once established, it produces fair crops for many years. The forage is palatable and of good nutritive value, but it is a difficult crop to harvest and to handle. The seed, moreover, germinates very slowly and uncertainly; and it is a long time, usually at least three years, before the plants become fully established. During this time it would require cultivation or weeding. It should be sown in rows from 30 to 36 inches apart, in early spring on light soils.

(*g*) *The lupine* — The cultivated lupines, though extensively used in Europe, are very little known in the United States. There are three leading varieties: The White (*Lupinus albus*), the Blue, and the Yellow.

These varieties take their name from the color of the flowers. They are all annuals, but the forage is not very palatable. It contains a large amount of a bitter substance, which in large quantities is distinctly injurious. These lupines are not likely to prove of much value as forage crops. Sheep eat them more freely than other animals.

529. *Miscellaneous* — There is a considerable number of plants belonging to different families, other than those which have been considered, which have from time to time been more or less highly praised and recommended to American farmers. Among these crops, the only one which, in the opinion of the writer, is likely to prove of much value is rape, although under some circumstances the cabbage, white mustard, spurry, and prickly comfrey may prove of some use.

(*a*) *Rape* * (*Brassica napus*) — There are both spring and winter varieties of rape, but so far as the writer has observed none of the latter are sufficiently hardy for introduction into the Northern states. They are, moreover, valuable chiefly for seed production, and are not distinctively forage crops. Among spring varieties, the Dwarf Essex rape, which has been extensively tried both by experiment stations and practical farmers in many of the Northern states, is coming to be highly valued. Rape belongs to the turnip and cabbage family, and is characterized by the peculiar strong flavor characteristic of all the plants of this family. This flavor renders these plants peculiarly palatable to all classes of stock, but at the same time makes it necessary that such crops be fed with some caution to milch cows, lest the flavor appear in the milk. They can be used in moderation, however, if fed immediately after milking. Dwarf Essex rape is exceedingly hardy and gives large crops, suited especially for folding. It is especially valuable for sheep and hogs. If not pastured too severely early in the season, rape will grow up again and again, furnishing in the course of the season a very large amount of feed in proportion to the area occupied. Like other members of this family, rape is exceedingly hardy and may be used for pasturage in fall later than almost any other crop.

* See Fig. 79, p. 358.

Soils and manures — This crop thrives upon a considerable variety of soils, but will do best on the medium loams, inclining rather to be light than heavy. The manuring for this crop should be the same as for the turnip (539, *a*).

Time and manner of sowing — The season of sowing rape should vary with the use to which it is to be put. It may be sown just as early in spring as the ground can be worked, if needed for summer pasturage. On the other hand, it may be sown as late as the end of summer if needed for autumn pasturage. It may be sown either broadcast or in rows far enough apart to allow cultivation. The latter method is preferable, especially in soils likely to grow up with weeds. The seed, which is similar in size and shape to the turnip seed, can be put in with drills adapted to sowing the latter. The quantity of seed for drill sowing is from about 1½ to 2 pounds per acre ; broadcast, 3 to 5 pounds.

(*b*) *Cabbage* (*Brassica oleracea*) — Some of the late and large varieties of cabbage are often used as forage crops. They may be cut and fed green, which will usually be the best method, or pastured. On strong, rich soils the cabbage gives very heavy yields, and, while ordinarily it may be worth more in the markets than for feeding, it is well to remember that there are few crops which will yield more of highly palatable food for stock than late varieties of cabbage.

Soil, manures, etc. — For discussion as to soil, manures, etc., see paragraph 550, *b*.

(*c*) *White mustard* (*Sinapis alba*) — This crop has many of the qualities of rape but is of much less general value as a forage crop. It should be sown broadcast in late summer or early autumn, and its most profitable use for forage will be to furnish late fall pasturage for sheep and young stock.

(*d*) *Spurry* (*Spergula arvensis*) — This is a very quick-growing crop which will produce considerable forage on soils too light and poor to produce good crops of most other kinds. The productive capacity is comparatively small. Its use is chiefly for soiling or pasture. It may be sown broadcast or in drills. In the opinion of the writer, it is not likely to prove of much value.

(*e*) *Prickly comfrey* (*Symphytum officinale*) — This is a perennial crop belonging to the dandelion family. It has long been known and frequently urged upon the attention of the farmers of the United States. While it gives large yields under suitable circumstances, the forage is not very palatable. Unless cut when very young, only the leaves are eaten. If cut early, it will furnish several crops in a season. It is propagated by dividing and planting the roots. The plants attain a large size and the distance between the rows and individual plants should be from 2½ to 3 feet.

LXXIV — SUB-CLASS III. CROPS CULTIVATED FOR THEIR SEEDS.

530. Most of the crops belonging to this division belong to the grass family, and they furnish by far the greater part of the food for the human race. Those belonging to the grass family, with the exception of Indian corn and Kaffir corn, have much the same characteristics as those exhibited by the grasses of our mowings and pastures. They have numerous fibrous roots which develop chiefly near the surface of the ground ; hollow, jointed stems ; long, narrow leaves in two ranks ; and perfect flowers. Nearly all of them are wind fertilized.

531. *Cereal grains* — The grains included in this class are called cereals or cereal grains from Ceres, the goddess of harvest. The cereal grains of the Northern latitude are wheat, rye, oats, barley, and Indian corn. All these grains excepting corn are alike in certain important characteristics of their growth, and these peculiarities will be here discussed.

(*a*) *Germination, root development, and stooling* — (Wheat, rye, oats, and barley.) All these grains germinate at a comparatively low temperature, and the young plant begins life under the most favorable auspices when the seed is covered to moderate depth, *i. e.*, from one-fourth to one-half inch in most soils. Whatever the depth to which the seed is covered, within such limits as permit germination, the first joint in the stem is produced a very short distance below the surface of the ground. This appears at first simply as a slight swelling on the slender, white stem. Even before the first leaf reaches the surface of the ground, a number of long, fibrous roots start from

the seed at the same point as that from which the stem grows. Within a short time after the leaves have come up into the air and light, roots start from the joint just beneath the surface of the ground. These multiply rapidly, comparatively near the surface. As soon as these roots are well established, the development of the primary roots, starting from the seed, ceases ; and in a comparatively short time all that portion of the plant below the joint, which was formed just beneath the surface of the ground, dies and gradually decays. The object of this peculiar development is evidently to enable the plant, whatever the depth to which the seed is covered, to

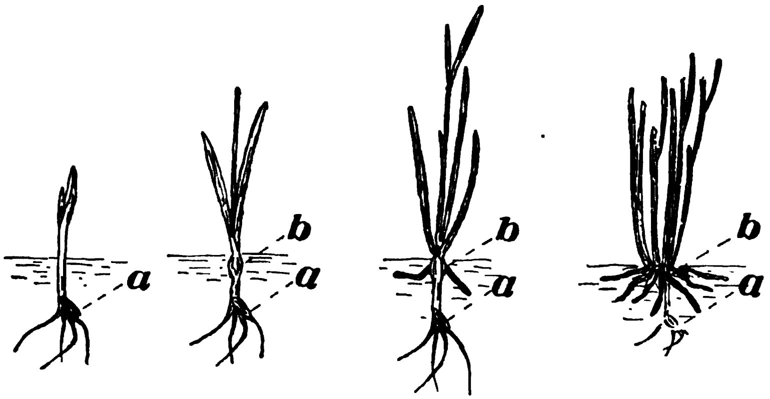


FIG. 148. WHEAT PLANT; shows rooting and stooling habit; *a*, seed; *b*, enlargement in stem from which the permanent roots and later stems start.

produce its roots in that part of the soil most favorable to their development, *i. e.*, comparatively near to the surface. The work of the seed and the primary roots is done when the secondary roots near the surface are well established. From what has been said it might be concluded that, since these grains have been provided by nature with means whereby their roots can be developed at the proper depth, however the seed may be covered, it can make little difference what the depth of covering is. Such is not the fact. If too deeply covered, since the store of nutriment in the seed is limited, it can produce only a very slender and comparatively feeble stem ; and under these circumstances, although the plant will in time recover, it makes a more feeble start than is desirable. It is from the same joint,

just beneath the surface of the ground, from which the secondary roots start that the new shoots which develop into the multiple stems found on a vigorous grain plant start. While all these grains have the capacity to produce numerous stems from the same plant, the extent to which they will do this is greatly affected by the conditions under which the plant grows. Among these conditions, the most important are the season at which the seed is sown, the thickness of the plants in the field, the fertility and the moisture of the soil. A protracted period of cool, moist weather is favorable to stooling. Grains which are sown late stool comparatively little. Thick-sown grain stools less than that which is more thinly sown, and the richer the soil and more favorable the moisture conditions, the more largely do these grains stool. Abundant stooling, provided the crop does not become overcrowded, which is liable to cause lodging, is desirable, as it means a heavy yield from comparatively little seed.

(*b*) *Wheat* — There are many agricultural species of wheat. Among these Common wheat (*Triticum vulgare*), Hard wheat (*Triticum durum*), and Speltz (*Triticum spelta*) are the only ones which are much known in this country. Emmer (*Triticum dicoccum*) and "*Einkorn*" (*Triticum monococcum*) are species known and somewhat widely cultivated in portions of Europe, where common wheat does not flourish.

Hard wheats (*Triticum durum*) are used in the manufacture of macaroni and vermicelli. Enormous quantities of these pastes are used in the United States, and they have been thus far for the most part imported. Increased attention is being paid of late years to the growth of wheat suited to their manufacture in this country.

Speltz is a variety of wheat to the kernels of which the husks for the most part adhere, less firmly but somewhat in the same manner as in barley. Speltz will thrive in localities where the more valuable varieties of wheat fail to grow.

Among *Common wheats* we have an enormous number of varieties. There are, in the first place, the two great classes, winter and spring wheats, and in each we have a large number of white and red varieties, awned and awnless varieties, varieties with chaff of different colors, etc. Winter wheats

are, for the most part, grown in the middle belt of states, from New York through Ohio, Indiana, Iowa, southward. These wheats are relatively soft and starchy, and are used for the manufacture of pastry flours. Spring wheats are grown in the states lying to the north of those named. They are hard and glutinous and are used for the manufacture of bread flours Wheat is now but very little grown in the New England states. Spring wheats only are successful, as a rule, in the four northern states of this section. Wheat raising is in general unprofitable in this region, as native wheat cannot compete with the cheap flour from the West.

Soils and manures — The most suitable soil for winter wheat is compact, clay loam. Spring wheat may be grown upon lighter soils, and on those containing more humus, than is best for the winter wheats. Thorough drainage is essential and, in localities peculiarly subject to rust, care should be taken that the wheat field is not too rich in organic matter. Wheat may be grown upon tenacious clays, but is more subject to winterkilling on soils of this class. Wheat follows clover better than it follows any other crop on all except very rich soils with abundant humus, where it may follow corn or oats. When winter wheat follows clover, but little nitrogen will be required, and the best form in which this element can be supplied, if at all needed, is as a top-dressing of nitrate of soda, about the time rapid growth begins in spring. One hundred and fifty pounds per acre will generally be an ample amount. If the clover has been manured as advised (518, *a*), *i. e.*, liberally supplied with materials furnishing lime, phosphoric acid, and potash, or if the wheat follows a crop of corn which has been well manured, the use of further manure or fertilizers may be unnecessary ; but, if the previous enrichment of the soil has not been attended to, then materials furnishing phosphoric acid and potash may be drilled in with winter wheat in the autumn ; or applied, either in autumn or in very early spring, for the spring wheat. Unless the soil is very thin, it will be unnecessary to apply any considerable amount of materials furnishing nitrogen in the autumn for winter wheat. Six hundred pounds per acre of mixture *A** is suggested as a suitable application to be drilled with winter wheat or harrowed in late in the fall in preparation for spring wheat.

* **For all fertilizer mixtures designated by letters, see pp. 539-541.**

Time and manner of sowing — Wheat delights in a somewhat compact condition of soil, and it is best that ground which is to be sown to winter wheat be plowed several weeks before the crop is to be sown, in all cases except upon the heaviest soils. Weeds should be kept down by harrowing, and rolling will be an advantage if the soil inclines to be light. For spring wheat, the land should be plowed the previous autumn and the seed bed made ready in the spring by harrowing. This makes it possible to sow early, which is most important, and insures the somewhat compact condition of the soil which is so desirable. Winter wheat may be sown from about the middle of September to the middle of October, earlier sowing being desirable on soils inclined to heave than on the lighter soils. Spring wheat should be put in just as early as the ground can be worked. Wheat can be better put in with a drill than in any other manner, and about 5 to 6 pecks of seed are required.

(*c*) *Rye* (*Secale cereale*) — Rye, like wheat, is divided into two great classes, spring and winter. There are comparatively few varieties of either class known in the United States, and only winter ryes are of any importance in this country. Throughout the Northeastern states, where rye is somewhat used both as a bread grain and for animal food, its cultivation for grain alone would not as a rule be found profitable. In many localities in this section, the straw sells readily at a good price and it is worth more than the grain.

Soil and manures — Among all the cereal grains, rye will make a profitable crop upon lighter and poorer soil than any other. This grain is therefore usually relegated to soils unfit for wheat. It is a splendid "rustler," and will outyield other grains under unfavorable conditions; but only on medium soils in good fertility does it reach its maximum product. Over-richness in nitrogen is not however desirable, as the tendency is to rank growth of straw and poor yield of grain with great liability to lodging. As a rule, rye succeeds a manured crop such as corn or potatoes, and is grown without direct application either of manure or fertilizers. In many cases, no doubt, a moderate application of fertilizers will be found profitable. For winter rye, 400 pounds of fertilizer *A* * put on at the time the seed is sown

* For all fertilizer mixtures designated by letters, see pp. 539-541.

will often give a profitable increase, and on soils inclined to be poor from 125 to 150 pounds of nitrate of soda, applied when growth begins the following spring, will greatly increase the yield. The nitrate should not be used provided experience indicates that the crop is likely to lodge if the growth be rank.

Time and manner of sowing — Throughout the greater portion of the Northeastern states, rye should be sown from about the 10th to the last of September. Either drill or broadcast sowing will give good results, the quantity of seed varying from about 1½ to 2 bushels to the acre.

FIG. 149. 1, Common oat; 2, Naked oat; 3, Short oat.

(*d*) *Oats* — The oat is one of the most largely cultivated grains in the North Atlantic states. Cultivated oats belong to three species: *Avena sativa*, the common oat, in which the head or panicle is open, *i. e.*, with branches developing equally on all sides; and *Avena orientalis*, in which the panicle is closed, all the branches turning to one side; and *Avena nuda*, the naked oat. Only oats belonging to the first two classes are of any particular importance. Naked or hulless oats are not infrequently taken up by adventurers, who advertise them as something new and a great acquisition. They have been long known and are not regarded as valuable, simply because their productive capacity is so much less than that of the other

species of oats. Most of the oats of the first class are white, although there are both dun and black varieties. There are many kinds. Oats of the second species are represented in this country by the Black Tartarian and a few other sorts. There are winter varieties of oats, but none of these appear to have proved sufficiently hardy to be safe crops north of northern New Jersey. The Clydesdale, Probsteier, and Lincoln are all excellent varieties of white oats.

Soil and manures — A moderately heavy loam is the kind of soil that proves best suited to oats, though the crop may be expected to do fairly well on all except the lightest soils. Those overrich in organic matter tend to produce a rank growth of straw peculiarly liable to rust and lodging. Such soils cannot be depended upon to produce good yields of heavy grain. There are two reasons why the direct application of either manures or fertilizers for oats is not the rule : —

1st. The crop has a deep and vigorous root system and is a good "rustler."

2d. If the soil be made rich, especially in nitrogen, the oat is prone to lodge during our heavy summer showers. It is, therefore, the rule to depend upon the natural or accumulated stores of fertility, except when the oat is grown for fodder or upon thin soils. Except upon soils rich in humus, a light application of nitrate of soda as a top-dressing will be found highly beneficial. The needed quantity is seldom more than 150 pounds per acre. On soils exceptionally low in fertility, use 600 to 800 pounds per acre of fertilizer mixture *B* *.

FIG. 150. CLOSED PANICLE OAT. FIG. 151. NAKED OAT.

Time and manner of sowing — The oat thrives best upon soils which are moderately compact, and fall plowing should be the rule. Harrowing as soon as the soil can be worked in spring will finish the preparation, and the oats should be sown either in drills or broadcast just as early as the ground can be fitted. From about 2 to 2½ bushels of seed per acre are commonly required.

* For all fertilizer mixtures designated by letters, see pp. 539-541.

(*e*) *Barley* — Cultivated barleys are chiefly of three species, the division being based upon the number of rows: *Hordium hexastichum*, six-rowed barley; *Hordium tetrastichum*, four-rowed barley; *Hordium distichum*, two-rowed barley. Besides these species there is another species including naked barleys. These are not widely grown for the same reason as that which prevents extensive cultivation of naked oats; and concerning barleys of this type it must be added that they are not new, having been long known and cultivated in some countries. There are winter varieties of barley which prove hardy about as far north as Washington. Six-rowed barleys are most largely grown in this country, but in localities where barley is produced chiefly for the use of the brewers those of the two-rowed type are preferred. Barley is not much raised as a grain crop in the Northeastern states.

FIG. 152. TWO-ROWED BARLEY.

Soil and manures — Barley needs a well drained soil, medium to light. The soils should be in a higher condition of fertility than for the other grains, but must not be overrich in nitrogen, if the grain is to be used for malting. Barley on such soils inclines to lodge and the grain contains too high a proportion of nitrogen. Barley should usually follow a well manured and carefully cultivated hoed crop, such as sugar beets, potatoes, or corn. If it follows such a crop, it will usually require little or no further nitrogen manuring, nor, indeed, any very large amount of fertilizers of any kind. In case the soil is deficient in fertility, apply per acre from 600 to 800 pounds of fertilizer mixture *B*.

Time and manner of sowing — Barley should be sown a little later in the spring than oats and in the same manner. From about 1½ to 2 bushels of seed to the acre are required.

532. *Intertillage of the small grains* — The American farmer as a rule

does not give the small grains under consideration any cultivation. It is believed that it would often pay. The average yields of these grains obtained by the farmers of the United States are much below those obtained in some of the older countries, under their more careful system of farming. When these grains are sown in drills, the space between the drills can be hoed by means of special grain hoes (horse) made for the purpose. When sown broadcast, either the weeder or the harrow may be used. On the lighter soils the weeder would probably answer, but in all cases where the soil tends to become quite compact the harrow, either of the smoothing or spike-tooth class, will be found preferable, one or the other of these being used according to the degree of compactness of the soil. The use of any of these im-

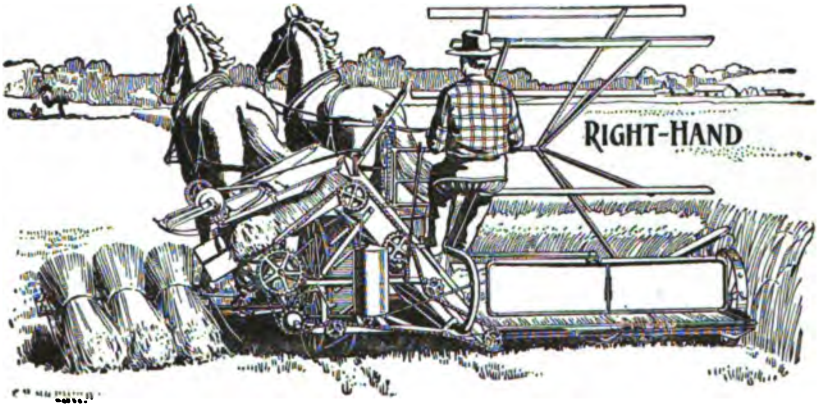


FIG. 153. TWINE-BINDING REAPER.

plements will undoubtedly destroy a few grain plants, but if judiciously used the amount of good accomplished will far offset any damage due to this cause. Weeds can be kept down to a considerable extent, and a soil mulch can be maintained which will prove effective in conserving soil moisture. Harrowing, moreover, has a tendency to increase the extent to which these crops stool.

533. *Harvesting the small grains* — The degree of maturity which the grains under consideration should be allowed to reach before harvesting dif-

fers with the climate and with the use to which they are to be put, and is, moreover, quite different for the different grains. Oats, on account of the tendency to shell and waste, must be harvested earlier than other grains, usually when in the dough. Barley, on the other hand, especially if to be sold to brewers, must be allowed to become dead ripe before cutting. Wheat and rye yield grain of superior quality if cut shortly before full maturity. The proper condition has been reached when the kernel can be indented under the pressure of the thumb nail, but not crushed. In the case of these grains and barley, however, it is customary to wait until the straw is for the most part yellow. Oats may be harvested while much of the straw still shows considerable green.

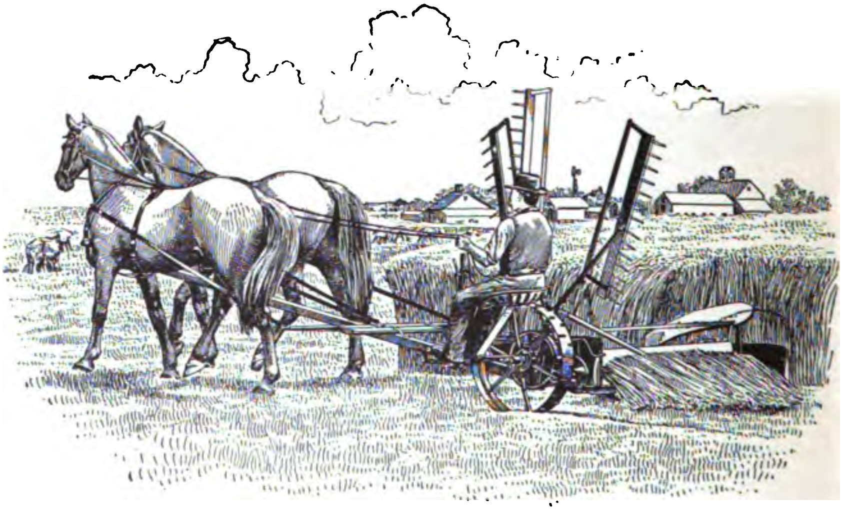


FIG. 154. SELF-RAKE REAPER.

Twine binding harvesters and binders are now, for the most part, used in cutting these grains, although in some sections, where the grain cannot be allowed to stand until perfectly ripe on account of climatic conditions, the self-rake reaper, which cuts and leaves the grain in bundles which are later bound by hand, is preferred. In the uncertain climate of the North-eastern states grain should, as a rule, be stooked after binding. All these grains are now threshed by machine, wherever grown to any considerable

extent. Rye, however, on the small scale in which it is grown in the New England states, and where the straw is needed for some manufacturing purpose, is sometimes threshed by hand, since the straw is less injured by such threshing than by machine.

534. *Diseases of the small grains* — All of the small grains under consideration are more or less subject to rust. No successful method of preventing rust has been discovered. It is known, however, that when grown in localities sheltered from wind, when sown too thickly on soils unusually rich in humus, the crop is likely to be seriously affected. Wheat is injured to some extent by two other diseases, loose smut and stinking smut or bunt. These diseases, like rust, are due to the growth in the plant of a parasitic fungus. The black powder, which develops in the ears in place of the grain, is composed of the spores of these parasites. Oats also are affected by loose smut and often to a much more serious extent than wheat. Barley, too, is sometimes affected but, as a rule, not seriously. Both the loose and the stinking smut, in the case of all these grains, can be prevented by proper treatment of the seed sown. The fungus which does the mischief comes from spores, black powder, which, in the form of dust, cling to the seed which is planted. These spores are very small and their vitality can be destroyed by soaking the seed from 10 to 15 minutes in water at a temperature of 132° to 135° F. An accurate thermometer should be used and the temperature carefully maintained at the point named. The seed should be thoroughly agitated or stirred, so that all parts of every kernel may be reached by the hot water. This treatment not only does not injure the vitality of the seed, it seems to increase it, for the increase in yield from seed subjected to this treatment has often been found to be greater than the amount of smut prevented accounts for. Rye is sometimes affected by a disease known as ergot. Common names used to designate this are spurred or horned rye. This disease also is caused by a fungus. It seldom destroys any considerable proportion of the crop. Here and there a kernel in a head fails to develop, in place of it a long, hard, black body, something like the spur of a cock, being produced. This, if fed to animals or eaten by persons in any considerable quantity, may

produce serious results. It is difficult to separate ergot from the healthy grain on account of the similarity in size and weight to the grain itself. No successful method of treatment is known. Rye known to contain ergot should not be used for seed, and a field which has been found to produce rye affected by this disease should be used for some other purpose.

535. *Indian corn* — Indian corn is in a certain sense the foundation of the agriculture of all the north portion of the United States. It is by far the most important crop. This was true even when Indian corn was used almost exclusively as a grain crop. It is doubly true since the crop is more extensively used for ensilage. The United States produces more Indian corn than all the rest of the world put together. The annual crop of this grain has frequently exceeded 2,000,000,000 bushels and often amounts to from 30 to 35 bushels for each man, woman, and child in the country. This crop is used chiefly as animal food, though all over the country it is also used to a moderate extent as a bread grain, and very extensively in the manufacture of glucose, starch, and whisky. Our climate and soils are splendidly adapted to this crop. Of tropical or sub-tropical origin, Indian corn is a child of the sun. The sun is the source of all power. Food is potential power. It has been well said that the Indian corn rolls up more sunshine in its leaves, and thus stores away in its seeds more potential power, than any other grain. The fact that our climate is so well suited to this crop gives us one important advantage in agricultural competition with such parts of the world as are not adapted to it, for it enables us to produce a most cheap food both for beast and man. Much of the corn used in the Northeastern states comes from the West. On the virgin soils of the West corn can be produced without doubt at a lower cost than in these states, but it may be doubted whether our farmers cultivate corn as extensively as they well might. Grown under the right conditions, it can be produced at a figure which makes it fairly profitable even at the relatively low prices forced by the competition of the West.

The varieties of corn which may be produced at a profit in the Northeastern states belong to three classes: flint, dent, and pop corns.

Flint corns are most largely grown in the north portion of the North-

FIG. 155. FLINT CORN, LONGFELLOW.

eastern states and among the leading varieties, mentioned in order of their probable earliness, are the Early Yellow Canada, Rhode Island White, Compton's Early, King Philip, Waushakum, and Longfellow. Compton's Early is a ten to twelve rowed variety. All the others are eight-rowed. The King Philip variety produces grain of a dark red color; all the others, save the Rhode Island White, produce yellow grain.

Among varieties of *dent* corn which can be successfully grown as far north at least as central Massachusetts, are the Early Mastodon and Sibley's Pride of the North. Henderson's Eureka and Leaming can be grown about as far north as the latitude of New York city.

Pop corns are simply a special division of the flint corns, characterized by very small, excessively hard kernels. This crop is often a profitable one, selling at a good price in many sections. Nonpareil is a very early eight-rowed white corn. It can be grown well to the north,

but does not sell as readily as the so-called rice corns. Early Amber rice can be grown as far north as central Massachusetts, but the white rice varieties, which are the favorites in the market, require a longer season.

(*a*) *Soils and manures for corn* — A profitable crop of corn may be grown upon soil of almost any class, except extremely heavy clays, provided the drainage is good. It is most at home and makes most profitable crops upon medium loams, fairly rich in humus. Enormous crops of corn may be grown by the use of farmyard manure alone. Corn is a rank feeder. It makes most of its growth after the weather has become thoroughly warm, and is, therefore, capable of utilizing the nitrogen of farmyard manures as it is rendered available by the action of natural agencies (133, *a*). It is possible to produce corn more cheaply than can be done by the use of farmyard manure alone, by suitable rotation and by the use of fertilizers, at least in part. If corn is produced by the application of very heavy dressings of farmyard manure and the field be then seeded, as is a common practice (516, *b*), grasses will predominate in the mowing. The proportion of clovers will be comparatively small. If, on the other hand, the dressing of manure is moderate and a considerable amount of fertilizers containing especially phosphoric acid, lime, and potash be used in connection therewith, the mowing will show then a far larger proportion of clover. The hay produced, though less desirable for market (518, *a*, *b*), will have far higher value for feeding at home (517, *b*). The clover will take its

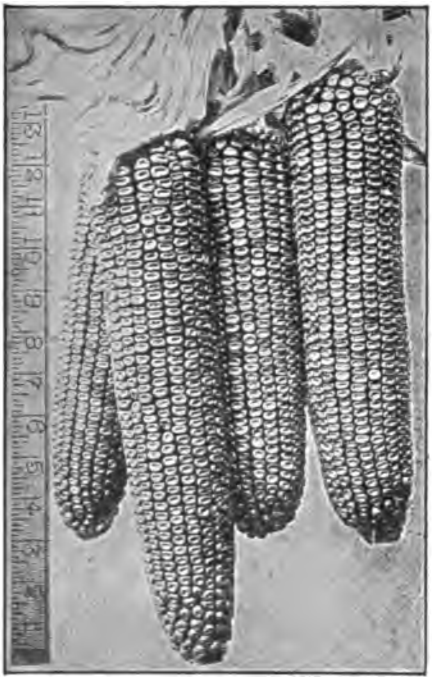


FIG. 156. EUREKA DENT CORN.

nitrogen from the air, and will leave the soil well stocked with that element. If then corn, potatoes, or other hoed crop not of the clover family, follow on the clover sod, the necessity for purchase or application of nitrogen-containing manures (always the most expensive) is greatly reduced. On the grounds of the Agricultural College in Amherst are four quarter-acre plots where, for the last ten years (1901), two of the plots have been manured yearly at the rate of 6 cords per acre of farmyard manure ; the other two with at first 3 cords and later 4 cords of similar manure, and at the rate of 125 pounds per acre of a high-grade potash salt, muriate or sulfate. The corn crop last year, on the full manure, was at the rate of 72.5 bushels of grain and 6,640 pounds of stover per acre, while on the smaller quantity of manure and high-grade sulfate of potash it was at the rate of 72.4 bushels of grain and 6,800 pounds of stover per acre. The crops were practically identical, but the cost of the small quantity of manure and the potash is about $6.40 less per acre than the cost of the larger quantity of manure used alone on the other plots. And this field, having been seeded to a mixture of timothy, redtop, and clover, at the present time (June, 1901), shows a far better growth of clover on the plots where the potash was used in connection with the manure than on the others. If fertilizers alone are to be used for the corn crop (and experience has demonstrated abundantly that a crop can be profitably produced by their use), care should be taken that the element potash is abundantly supplied. The crop should be rotated with grass and clover, and if potash together with phosphoric acid and lime have been liberally used for the clover crop, it will be unnecessary to apply any very large amount of fertilizers supplying nitrogen, the corn crop deriving this from the decaying clover sod.

On one of the fields on the grounds of the Agricultural College at Amherst is a plot of land which for ten years had been manured yearly with dissolved boneblack and muriate of potash, and which had received one application of lime in the spring of 1899 at the rate of one ton to the acre. This plot gave a yield at the rate of 60 bushels of shelled corn in the tenth year of the experiment. For use in connection with very moderate quantities of farmyard manure, it is suggested that from 600 to 800 pounds per

acre of mixture C* be spread broadcast and harrowed in. For use on clover sod in fair condition of fertility without other manure, 800 to 1000 pounds per acre of mixture D*, also spread broadcast and harrowed in. For use on soils comparatively poor and relatively deficient in humus, 1200 to 1500 pounds per acre of mixture E* applied in the manner already indicated.

Not a few farmers are in the habit of using fertilizers in the drill or hill for corn. It is not believed that this is desirable unless the soil be exceptionally poor. The roots of corn extend rapidly through the soil and within a very short time fill the entire ground.

(*b*) *Time and manner of planting*. If corn is to be planted upon sod land, the field should be plowed in the fall and fitting completed by the use of harrows, which will leave the soil light and mellow. If grown after a hoed crop, the field should be plowed in the autumn if the soil be heavy, and may be replowed in spring. Corn delights in a soil in very light and mellow condition, differing in this respect from the small grains. Nothing is gained by planting before the soil and weather are warm. The unfolding of the leaf buds of the tree is a good indication that the time when corn may be planted is at hand. Corn is planted both in hills and drills and there does not appear to be much difference in yield under the two systems. If planted in hills, the field can be cultivated in both directions, and this may somewhat reduce the cost of caring for the crop. With modern implements, however, the crop can be successfully cared for if put in drills, and it is believed that this method should usually be preferred. Especially is this the case if it is to be cut by the use of a harvester. If to be cut by hand, the work is somewhat less if the crop is in hills. Corn should be planted by machine, and there are many kinds well adapted to putting the

FIG. 157. Corn crop from 1-20th acre, after eleven years' continuous manuring with dissolved boneblack 320 pounds, and muriate of potash 160 pounds per acre. For comparison the yield on a plot not manured for eleven years is also given.

* For all fertilizer mixtures designated by letters, see pp. 539-541.

seed in either in hills or drills. The quantity of seed needed per acre, when grown for grain, is about 8 to 10 quarts.

(*c*) *Cultivation of the corn crop* — The weeder and smoothing harrow should be mainly depended upon in the tillage of the corn crop. Frequent, shallow, level intertillage should be the rule. Never allow the weeds to start. Maintain a surface mulch. These should be the watchwords in corn culture. If thoroughly acted upon, there will be no occasion to use the hand hoe, which greatly increases the cost of caring for the crop.

(*d*) *Harvesting the corn crop* — The nutritive value of the stalks of corn is so great that no system of harvesting is worth attention which does not secure stover as well as grain in good condition. The wasteful methods so long exclusively followed in the West, of husking in the field and allowing the stalks to stand, is being gradually given up in many parts of that section. The old system in many parts of New England of cutting the portion of the stalk above the ear, allowing the balance to stand until it is ripe, should also be given up. True, it secures the top stalks in splendid condition ; but the lower portion has little food value. In all the New England states, where fodders have a relatively high value, the crop should be harvested by cutting to the ground, and putting up in stooks. Cutting should take place while the stalks are still comparatively green. As soon as flint varieties are glazed, or dent varieties show the dent in the end of the kernel, the crop is ready to cut. The crop of the Northeastern states is still very largely cut by hand by the use of the corn knife ; but the corn harvesters, invented primarily for use in cutting ensilage corn, may be used in cutting corn grown for grain as well, and their use will considerably reduce the cost of harvesting the crop. Corn should be set up in stooks of good size soon after it is cut, and the stooks should be securely and tightly bound at the top. With care in building the stooks and tight binding at the top, very few will be blown down by the autumn winds. The Unadilla tie, consisting of a bent wire clasp and a stout cord, greatly facilitates the work of binding the stooks. Corn usually stands in stooks until the stover is well cured, at which time the ears will be found moderately dry and hard. Husking is still almost entirely done by hand. Corn husking machines were invented

a good many years ago, but their employment is not a great success. They do the work fairly well but there is no considerable saving in cost. A combined husker and fodder shredder has been put upon the markets, with the idea that the stover shredded at the time of husking and packed into the silo would prove of greater value for feeding than stover otherwise handled. On the whole, the results have not been entirely satisfactory. If the stover is to be put into the silo, then it is preferable to break the ears from the stalks at a period a little later than that which has been indicated as the

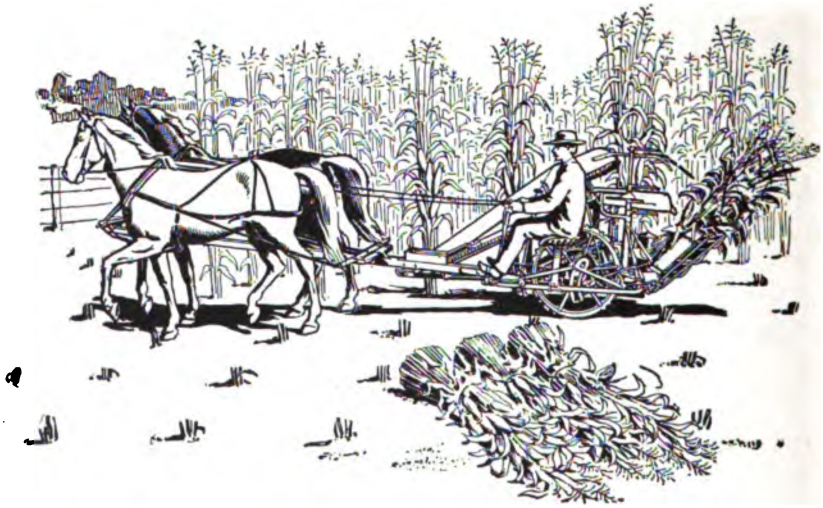


FIG. 158. CORN HARVESTER.

proper time for cutting, throwing them into windrows in which they may lie a week or two, to be later husked by hand, and then cutting the stalks at once either by hand or by the harvester, and hauling immediately to the silo. Put in green in this manner, much better silage is secured than in case the crop is first stooked and the dry stover ensiled. Indian corn requires careful storing in the climate of the Northeastern states or the grain will not cure satisfactorily. Cribs should be of moderate width (four to five feet) and so constructed as to allow the freest possible circulation of air. In the climate of this section the stover seldom becomes sufficiently well

cured to keep if stored in large masses. It may be built into large stooks at the time of husking and left in the field to be hauled in about as required, or it may be taken to the vicinity of the barn and put into small stacks. It seldom cures sufficiently well to keep in mows in a barn.

(*e*) *Diseases* — The corn crop is fortunately remarkably free as a rule from diseases of a serious character. Smut is the only disease ordinarily troublesome. Smut is due to the growth within the plant of a parasitic fungus, and the whitish swellings which appear most commonly upon the ears, but sometimes upon other parts of the plant, and which are filled with a mass of black material—at first moist and pasty, later dry—are the fruiting parts of this fungus. The black powder consists of an enormous number of spores. The extent to which the crop is injured by smut varies widely in different seasons ; to some extent, also, with the locality, and to a considerable extent with the variety. Many of the early sweet corns are peculiarly liable to injury from smut. Thus far no practicable method of surely preventing corn smut has been discovered. The crop is so universally and extensively grown, and manures, so often made from animals fed on corn stover or silage, are so largely used for it, that the spores from which this smut is developed are practically everywhere abundant in the fields in which corn is grown. Smut spores may be carried to the field with the seed, to which they adhere in the form of dust. Infection of the crop from this source may easily be prevented, in the manner indicated in discussing the smuts of the small grains (534). Such treatment ordinarily proves of little use, for it can do little good to destroy a few hundreds of spores on the seed when there are probably millions waiting in the soil, or in the manure. It is sometimes advised that the smut swellings be collected before the scattering of the spores, but, while this may be advisable in gardens, it is not ordinarily practicable in fields. Rotation, in case a field becomes badly infected, seems to be the only practicable course, and even this is not likely to insure entire freedom from the disease, on account of the enormous number of spores and the facility and certainty with which they are distributed.

536. *Miscellaneous grains* — (*a*) *Kaffir corn.* Kaffir corn is being in-

creasingly grown in the semi-arid states, on account of its remarkable ability to resist drouth. It will be remembered that this is a sorghum, producing seeds in the tassel at the top of the plant. In some parts of the semi-arid states hot, drying winds are likely to come at the time Indian corn is in flower, not infrequently destroying the prospect of a crop. The vitality of the parts of the flower being destroyed, no crop is possible, though the weather may soon become much more favorable. Kaffir corn has the ability to go through such periods, and if the weather is later favorable will mature a fair crop. The grain appears to be slightly inferior in feeding value to Indian corn, but may be used for most of the purposes for which the latter is more commonly employed. Kaffir corn requires similar soils and manurial treatment to Indian corn. It is not recommended for culture in localities where Indian corn succeeds.

(*b*) *Millets* — A number of the millets are extensively used in the Orient as grain crops, the seed being used as human food in a great variety of ways. In nutritive quality, millet seed ranks high ; but it is less desirable than the product of our ordinary grains. It cannot be made into good bread. Millet seed is a useful food for poultry, and some varieties are in considerable demand for bird seed. It is believed that the Japanese varieties of each of the three species of millets will be found superior in their capacity for seed production to most others, for all localities except such as are peculiarly liable to serious drouth.

The Japanese foxtail millet produces a small, yellow seed and has given yields, on land which would produce from 50 to 60 bushels of Indian corn, of about the same number of bushels of well cleaned seed.

The Japanese broom corn millets produce a much larger seed, but do not give as good yields. On land where Japanese foxtail should give 50 to 60 bushels, the broom corn variety would probably yield 35 to 40 bushels.

The Japanese barnyard millet has enormous capacity for seed production. The seed is small and brownish in color. Yields of from 60 up to 90 bushels per acre have been frequently obtained. Two brothers in Sunderland, Mass., harvested, in the year 1900, rather over 500 bushels of seed from six acres of land, and there was much waste owing to their inexperience in

handling the crop. The seed of this millet is strikingly like oats in composition; the percentage of each of the leading food constituents is almost exactly the same as in average oats. Experiments in feeding meal made by grinding the seed of this millet to milch cows indicate it to have equal value with oatmeal as a constituent of a mixed grain ration for milk production. The seed is so small that grinding is necessary if the seed is to be fed to horses, cattle, or sheep.

The foxtail or broom corn millets do best upon medium to light loams; the barnyard millet on medium to heavy loams, rich in humus. These crops may be manured as advised for corn. Grown extensively as seed crops, they should be harvested in the same manner as the cereal grains.

FIG. 159. JAPANESE BUCKWHEAT.

(*c*) *Buckwheat* (*Fagopyrum esculentum*) — This crop is quite widely grown, chiefly for use as human food, though to a considerable extent for the production of grain for poultry. The Japanese buckwheat, of comparatively recent introduction, and the Silver Hull, have considerably greater capacity for production than the ordinary buckwheat. Indian wheat (*Fagopyrum tartaricum*) is closely allied to buckwheat. It will thrive under conditions less favorable than those required by the latter. The grain is smaller and of inferior value. Buckwheat, though usually classed with the other grains, belongs to an entirely different family of plants,— the smartweed family. The flowers are perfect and contain a large amount of honey, this crop being among the most useful that can be sown to furnish pasturage for bees. Buckwheat is capable of making a crop on comparatively light and poor soils. It grows rapidly and is a good "rustler." For these reasons it is not infrequently

grown as a catch crop, and for the same reasons it is not common to use manures and fertilizers for it. It is sown broadcast, the amount of seed per acre usually ranging from about 3 to 4 pecks. Much care is necessary in harvesting to avoid waste from shelling.

537. *Legumes* — (*a*) *Peas*. Peas are comparatively little grown as a grain crop in the Northeastern states, although it is recognized that pea meal constitutes a valuable feed for many kinds of stock. In suitable soils and climates, peas may be expected to give a yield of from 30 to 40 bushels of seed per acre, and with such yields a crop would be profitable, as the nutritive value of the pea is so high. The climate of the greater portion of that section of country under consideration is characterized by too intense summer heat, too great liability to drouth, to make the pea an altogether safe and satisfactory crop. To do its best, it requires a cool and moderately moist climate, and it is much more reliable in Canada than in most parts of the United States. Among the varieties which will be most satisfactory are the Canada white field and the Canada blue field pea.

Soils and manures — Peas give most satisfactory crops on deep, cool, moderately heavy loams, which should be well enriched, or naturally well stocked, with lime, phosphoric acid, and potash. It can derive most of its nitrogen from the air, as has already been pointed out. To depend exclusively upon farmyard manures for this crop would be unwise, for these supply relatively too much nitrogen. It will be better to depend upon fertilizers, and, if these can be put on in the fall, it is recommended that from 600 to 800 pounds of mixture *A* * be spread at that season. If not applied until spring, then use 500 or 600 pounds of mixture *D* *,— in both cases broadcast. As a field crop, the pea is generally sown as early in spring as possible, either broadcast or with a grain drill, the latter being best. From two to three bushels of seed per acre are required. The crop may be harvested either by cutting with a mowing machine or the self-rake reaper, especially modified to suit this crop. It should be cut as soon as the pods are about two-thirds yellow. Peas require careful handling in order to avoid shelling. They can be threshed either by hand or by the use of the ordinary threshing machine.

* For all fertilizer mixtures designated by letters, see pp. 539-541.

(*b*) *Beans* — Field beans belong to a number of distinct species. The most important of those which may be grown as farm crops are the ordinary white pea bean (*Phaseolus nanus*), soy bean, and the horse bean. The latter is *Vicia faba.*

The white pea bean, in those sections having suitable soils, is often a profitable crop. It is extensively grown in New York.

The soy bean has been sufficiently described as a fodder crop. Its use as a grain crop is not yet well established; and the position which it will ultimately occupy as a grain crop cannot yet be foretold. There are varieties adapted to almost all portions of the United States. One of the best for the southern half of the New England and Middle states is the Medium Green. Farther north it is doubtful whether any varieties giving a sufficiently large yield to be really profitable will mature; but the Early White will ripen wherever the Canada yellow corn matures. The Medium Green, on suitable soils, may be expected to give yields of from 30 to 40 bushels where corn would give from 60 to 70 bushels. The seed is much superior to corn in nutritive value, especially in flesh-forming constituents and fat. Experiments indicate it to have about equal value to cottonseed meal as a food for milk production, but it may be doubtful whether, under the conditions usually existing on the farms of the section under consideration, it will not be wiser to purchase such feeds as cottonseed, linseed, and gluten, which will furnish flesh-forming constituents in abundance, than to undertake their production at home. Whether this will be the case must depend in large measure upon the location. On farms well situated for the marketing of money crops, it is believed that it will be wiser to devote a portion of the farm area to the production of a money crop adapted to the soil and market conditions, and to purchase feeds. On the other hand, on farms situated in rather inaccessible localities, where the facilities for the disposal of money crops are poor, and where soils of suitable character for the soy bean are found, it may be wise to raise this crop extensively, thus reducing the expenditure for grain.

The horse bean, though very largely grown in Great Britain and in some parts of Europe, is not very well adapted to the climate of the sec-

tion under consideration. It is a much more certain crop where the season is cool and the rainfall more evenly distributed. Its culture as a grain crop in the New England and Middle states is not recommended.

Soils and manures — Both the white pea and the soy bean need soils of the same character as corn, *i. e.*, the medium to light soils. The horse bean requires a more heavy soil, retentive of moisture, and deep. No inconsiderable share of the advantages to be derived from the culture of these crops lies in the fact that they do not need nitrogen manuring to any considerable extent, as they have the same capacity to assimilate atmospheric nitrogen as all other legumes. Farmyard manures, therefore, should not be used for them and fertilizers should be selected as recommended for peas. If they can be applied in the fall, use from 600 to 800 pounds mixture *A**. If fertilizers must be put on in the spring, 500 to 600 pounds of mixture *D**.

Time and manner of planting — Both the white and the soy bean should be planted in drills by machine; the distance between the drills, about 2½ feet; season, just after corn planting. About one-half bushel of seed per acre is required.

Cultivation — Beans should be cultivated only when the vines are dry, as working when the vines are wet is likely to increase the extent to which they suffer from blight. Intertillage can be given while the vines are small, by means of weeders; later, with such cultivators as are used for corn, the soil being kept level, — shallow culture to maintain a surface mulch should be the rule.

Harvesting — The bean is rather a difficult crop to cut on account of the tough, woody character of the stems. The most successful machines are those which cut just beneath the surface. The crop requires careful handling. It should be cut before the pods begin to become dry. After cutting the beans may either lie on the ground as cut or, better, unless they can be promptly threshed, built into small stacks, using care not to allow the pods to come in contact with the ground. When thoroughly dry, they should be threshed by machine, if grown upon a large scale. Special bean threshers are made for the purpose. They work upon the same principle

---

* **For all fertilizer mixtures designated by letters, see pp. 539-541.**

as grain threshers, but must operate at a lower speed and use different sieves.

LXXV — SUB-CLASS IV. CROPS CULTIVATED FOR UNDERGROUND PARTS.

538. *Root crops* — The root crops in general require rather deep, mellow soils and medium loams are in general most satisfactory. The soils should be rich, especially in potash and lime, and large amounts of available nitrogen are necessary for the most profitable results for all except the sugar beet when grown for use in the manufacture of sugar. The labor cost in the case of all these roots, except perhaps the English turnip, is relatively high. Hence the soil must be well stocked with the elements of fertility. It would be highly unwise to meet the heavy expenditure necessary for labor under conditions where, owing to deficient fertility, a small crop only can be expected. Further, owing to the small size and comparatively slow growth of most of these roots at first, care should be taken to put them on land which has been so managed that it is not likely to become exceptionally weedy.

539. *English turnips* (*Brassica rapa*) — All varieties of English turnips are characterized by remarkably rapid growth. Many of the smaller varieties require so few weeks to reach maturity that they are often grown as catch crops, or second crops following early potatoes, early peas, or something of that description. These varieties are for the most part white fleshed, the flesh is comparatively soft, and they do not keep very well. There are many varieties. Among the best for use as catch or second crops the Strap-leaf Redtop and Strap-leaf Whitetop are recommended. The purple top White Globe is somewhat thicker and larger. It is also a quick-growing variety. The White Egg is a fine table variety. Some varieties are long or tankard shaped, but these are not generally grown in the United States Long White Cowhorn and White Tankard are of this type. The English turnip is in considerable demand for table use; but as grown upon the farm its chief value is as stock food, being especially relished by sheep and cattle and particularly valuable for the former.

Soil and manures — The English turnip will grow a root of better

table quality on soils rather lighter than those suited to the root crops in general. It is a rank feeding crop; farmyard manures may be wisely used for it, and these may well be supplemented by superphosphates. If fertilizers alone are employed, from 800 to 1000 pounds of mixture *F** should be used. The smaller, quick-growing English turnips are not infrequently sown broadcast and fair crops are obtained, the seed being put in from about July 25th to August 10th, in the latitude of central Massachusetts. The larger sorts should be planted in drills, the distance between which should vary with the size of the variety, usually from about 16 to 20 inches.

540. *Swedish turnip or ruta-baga* (*Brassica campestris*) — Swedish turnips are for the most part larger, require a longer season, have firmer flesh and better keeping qualities than the English turnip. They are grown as farm crops, both for table use and as stock foods. They require about the same soil, manure, or fertilizers as the English turnip; but the latter should be used in larger quantities, as the Swedish turnip is a rank feeding crop. It is capable of giving yields of from 18 to 25 tons per acre under favorable conditions. Among the many useful varieties, Laing's Improved and Long Island Improved purple top are recommended.

541. *Harvesting turnips* — All turnips, both of the English and Swedish varieties, are exceedingly hardy and may be left in the ground until there is danger that the soil will freeze, — in central Massachusetts, usually until about November 5th to 15th. All turnips grow partly above ground, and are readily pulled. The tops should be cut close to the roots.

542. *Beets* (*Beta vulgaris*) — Two distinct classes of beets are grown as farm crops, known respectively as the mangel-wurzel and the sugar beet. The latter, however, appears to be only a highly improved and selected type of the first. If grown for stock food, for which purpose it is considerably used, the sugar beet requires precisely the same treatment as the mangel-wurzel. If to be used for sugar manufacture, it should be somewhat differently treated and will, therefore, be specially considered.

(*a*) *The mangel-wurzel, written also mangold wurtzel, is for brevity often called mangel or mangold* — There are many varieties, differing in shape, size, and color. The Globe varieties, among which the Yellow Globe

* For all fertilizer mixtures designated by letters, see pp. 539-541.

is perhaps as good as any, are characterized by solid flesh, moderately large size, and good keeping qualities. The long varieties reach a larger size, are usually not quite so solid fleshed, and are often somewhat inferior in nutritive value to the Globe sorts. The Norbiton Giant Long Red is one of the best known. This variety is capable of giving enormous yields, and, growing half or more above the surface, is easily harvested. The Ovoid varieties are intermediate in form between the two described and in quality are about like the Globe sorts.

Soils and manures — Mangels require deep, rich, mellow loams. They are rank feeders. Heavy applications of farmyard manure are advisable, and in connection with manure some fertilizer is often employed. For use with manure, from 600 to 800 pounds per acre of mixture *G** are recommended; for use alone, from 1500 to 1600 pounds of the same mixture. It is generally considered desirable that potash salts for beets should be applied in fall, and better results are likely to be obtained by following this course. The beet is a deep rooting crop and it is desirable that the potash shall, to a considerable extent, have washed into the lower strata of the soil. If the potash is applied in spring, it is likely to remain too near the surface for the best growth of the beet throughout the following growing season. Mangels should be sown early in the spring, in drills from 27 to 30 inches apart, according to the size of the variety. From 4 to 6 pounds of seed to the acre are required. The plants should be thinned while young to from about 8 to 12 inches in the row. Careful culture and hand weeding are essential. These roots are less hardy than turnips and should usually be harvested, in the latitude of central Massachusetts, not later than about October 20th. The roots keep better if the leaves are twisted off than they do if they be cut, and it is usually best to handle them but once, twisting off the leaves as the roots are pulled.

(*b*) *Sugar beets* — Within the past seven or eight years the cultivation of the beet in the United States, for sugar manufacture, has rapidly increased. Progress has been most rapid in California, Oregon, and the states of the north Mississippi Valley. There can be no doubt that more diversified agriculture in those districts is highly desirable, and that the pro-

* **For all fertilizer mixtures designated by letters, see pp. 539-541.**

duction at home, of a larger proportion of the immense amount of sugar used by our people, is also highly desirable from an economic point of view. The production of beets for sugar is hardly likely, in the opinion of the writer, to prove profitable in the New England states. In that section greater profit can be derived from the cultivation of numerous other crops, to which the soil and climate are suited, and which can be readily disposed of in the markets of that section of the country. Potatoes are far more profitable; tobacco, in certain sections, is more profitable. In some parts of the Middle states, the growth of the beet for sugar has been begun and the extent of the industry is increasing slowly. Whether it will prove very profitable in that section cannot yet be regarded as settled. Among the best varieties for sugar are Vilmorin's Improved and Klein Wanzleben. As a variety for stock food, Lane's American Sugar is valuable.

Soils and manures — The soil for the sugar beet should be, in general characteristics, similar to that which has been specified as suited for the mangel. Overrichness in humus or in available nitrogen compounds is undesirable, on account of the rank growth and relatively low percentage of sugar likely to be produced on such soils. It is of the first importance that the soil be deep, mellow, with good capacity for retention of moisture. Farmyard manures may be employed for this crop in moderate amount, but unless rotted it is better applied in the fall and plowed in. If rotted it may be plowed in in the spring. The fertilizers used must supply abundance of potash, and this, for the same reasons as indicated under mangels, is better applied in the fall. If fertilizers only are employed, mixture *G* * may be used with a single change: high-grade sulfate of potash should be put in place of the muriate. The quantity employed should be from 1,500 to 1,600 pounds per acre.

Time and manner of planting — The soil should be very carefully prepared. It should be deeply plowed in the fall, plowed again in the spring, and worked with the harrow until it is brought into fine tilth. It should have received such previous treatment as to be comparatively free from weeds, otherwise the labor cost of production will be heavy. Unless the

* **For all fertilizer mixtures designated by letters, see pp. 539-541.**

soil is mellow to good depth and perfectly drained, the roots are likely to grow in part above ground, and that portion that grows above ground is entirely unfit for use in sugar manufacture. The sugar beet should be sown in moderately early spring, in drills about 18 to 20 inches apart. Special machines, sowing a number of drills at one operation, must be used where the crop is largely grown. For sugar manufacture a root of moderate size, smooth and fine in quality, is an essential, and the crop should accordingly be allowed to stand considerably closer than is desirable if it is grown as food for stock. Roots weighing from about a pound to a pound and a half are as large as the sugar manufacturer desires. When finally thinned, the plants in the drill should stand about five or six inches apart.

Cultivation — Culture must be very careful, the root must be kept steadily growing from the start to maturity in order to develop satisfactory qualities. If the roots incline to grow above ground, moderate ridging is necessary.

Harvesting and storing — The sugar beet should be harvested before severe frosts. Special machines are made for loosening the roots, which are then pulled and the tops cut below the lowest leaf scale. The solid upper portion of the root covered by the leaf scales is unfit for sugar manufacture. The crop is worked up as soon after harvest as possible. That portion which must wait is best preserved in piles in the field, covered with earth as described below (545).

543. *Carrots* (*Daucus carota*) — The carrot is quite extensively grown as a farm crop, chiefly for stock food. In many parts of New England it finds a ready sale among horse keepers at profitable prices. Its use as a table vegetable is not extensive in most parts of this country. The carrot is very highly relished, and is a most wholesome and nutritious root, — the very best among all roots for horses. It would doubtless be much more largely grown but for the fact that, owing to the small size of the plants at the start, and their very slow growth, the labor cost of producing it is heavy. Among the best varieties for farm purposes are the Danvers Improved, a half-long variety more easily harvested than many, and the Improved Long Orange.

(*a*) *Soils and manures.* The soil for carrots should be a little lighter than for most of the root crops, and for the production of smooth roots it must be mellow and deep. It is especially essential that its previous treatment shall have freed it from weeds and weed seeds. Farmyard manures, if well rotted or free from weed seeds and worked into the soil in the fall, may be used, but owing to the difficulty of keeping such manures free from seeds of weeds fertilizers are preferred by many. The same kind and quantity is recommended as for sugar beets.

(*b*) *Time and manner of planting* — Carrots should be planted in middle to late spring. It is often a distinct advantage to work the field several times with a harrow before the seed is sown, in order to destroy the weeds which start early in the season. Very thorough preparation is essential, the operations being best finished by the use of the smoothing and Meeker harrows (174). The seed is put in by means of hand sowers in drills from about 14 to 18 inches apart, according to variety. About two pounds of seed per acre are required.

(*c*) *Cultivation* — This crop must be cared for mainly by the use of hand cultivators and hoes (190, 191). Never allow the weeds to get a start. Thin before the plants become slender and spindling, to a distance, according to variety, of from 3 to 5 inches.

(*d*) *Harvesting.* The carrot, growing entirely under ground, may remain out until later than the beet. It should be harvested before turnips usually in the latitude of central Massachusetts before the first of November. The labor cost of harvesting can be greatly reduced by the use of the plow, a deep furrow being opened as close to the row as possible. With the very long-rooted sorts a subsoil plow may follow the ordinary plow, the standard just to the left of the row, the wedge which raises and loosens the soil just beneath the tips of the roots. The use of the subsoil plow in this manner will start and loosen even the longest carrots, so that they can be readily pulled out by hand. It should be understood that the subsoil plow used as directed follows directly behind the ordinary plow which turns a furrow away from the roots. The tops of carrots must be cut by hand by the use of sharp knives. The roots should lie upon the surface until dry.

544. *The parsnip* (*Pastinaca sativa*) — The chief use of the parsnip in the United States is as a table vegetable, for which there is considerable demand. It is a palatable and extremely valuable stock food. In the Island of Jersey it is very extensively used as food for milch cows, for which it is especially valuable, being highly favorable to the production of a large quantity of milk of excellent quality. The chief reason why the parsnip is not more largely grown as stock food in this country is the fact that it is a rather difficult crop to harvest. It requires soil of the same character as that needed by carrots, but depth and a rather open and permeable subsoil are even more necessary than for that crop. The parsnip is exceptionally deep-rooted, its tap root often penetrating to a distance of 5 or 6 feet, and many slender feeding rootlets are produced to a depth of 2 or 3 feet. The parsnip, therefore, is preëminently a deep feeding crop. As regards preparation of soil, manuring, and time and manner of planting there is no essential difference between this crop and carrots. The drills should be about 16 inches apart. About 4 pounds of seed are required per acre. There are but few varieties of parsnips. The Hollow Crown and the Large Dutch are among the best. Parsnips can be economically harvested, as described for the long rooted carrots, by use of the ordinary plow followed by the subsoil plow. This root is exceedingly hardy. If needed for winter use, it must of course be dug in the fall, but if not needed until spring it may safely remain in the ground over winter.

545. *Storing roots* — All the root crops under consideration should be harvested if possible when the soil is moderately dry, in order that overmuch earth may not adhere to them. This, of course, is especially important in the heavier soils. They should lie upon the surface of the ground until outside moisture is evaporated. They may be stored in cool, dry cellars in moderate bulk. Bins so constructed that the air can circulate underneath and through the roots contained therein are desirable. These must be smaller in proportion as the roots are small and pack closely. Where sufficient cellar room is not available, any of these roots may be successfully kept in pits or heaps covered with earth in the open field. If properly put in, roots keep better so stored than in cellars, as in the cellar

they are more liable to lose moisture and shrivel. In thoroughly drained, light soil a pit from 2 to 2½ feet in depth and of a width varying with the size of the roots may be excavated, but as a rule it is quite as well not to dig a pit of any considerable depth. It is customary among large producers to plow a strip of such width as the distance between the wheels of an ordinary cart, and of such length as may be required, and to throw out the earth loosened by the plow. The roots are then backed into this shallow pit and dumped directly from the cart. The heap, which may be from 3 to 3½ feet high, and which should be well rounded on both sides, must of course be finished by throwing in some roots by hand. These heaps of roots for mangels and Swedish turnips may be about 5 feet in width. For sugar beets they should not be over 3½ to 4 feet, for carrots or parsnips or the smaller English turnips, not over 3 feet. The height in the middle of the pile for the larger roots may be about 3½ feet, for the smaller ones it should not be over 2½ to 3 feet. At the time the roots are put in, usually early in November, they will need but a little covering with earth; and to put on a heavy covering at that time would be a great mistake as the roots would begin to grow, which would seriously injure their quality and increase the probability of decay at a later period. Only 2 or 3 inches of earth are required at the start. This covering should be increased from time to time as the weather grows colder, and just before the date when freezing weather is expected the earth cover may be increased to a foot or a foot and a half. The heap should remain without further cover until the outside of the earth cover is moderately frozen, then straw, seaweed, corn stover, or litter of any kind convenient should be put on in such quantity as to prevent further freezing,—the amount necessary of course varying with the climate and with the probability or certainty of snowfall. These heaps in the open air may be of any length desired, and they should extend lengthwise in general from northwest to southeast. In this position they are less exposed to cold winds.

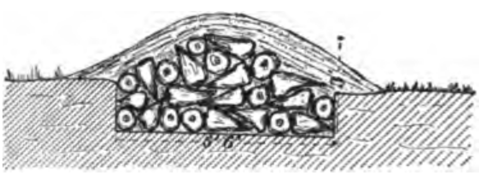


FIG. 160. ROOTS IN OPEN AIR PITS.

the snow drifts on the two sides more evenly, and the two sides are equally exposed to sunshine. Many recommend placing straw or similar material next the roots but, in the experience of the writer, roots are more likely to decay when covered first with straw than they are in direct contact with earth.

LXXVI — TUBERS.

546. *Potatoes* (*Solanum tuberosum*) — The chief use of the potato in the United States is as human food, though in localities especially suited to the crop, and with sparse population, it is, in years of abundance, extensively used as animal food. The potato is also employed largely in the manufacture of starch ; less largely in this country, however, than in others, for we have in Indian corn a very cheap and abundant source of starch. The potato is almost everywhere grown in the United States, as it adapts itself to a wide range of soil and climate. The average crop in the United States usually varies from about 75 to 90 bushels per acre. This is far below the capacity of this crop. Many good farmers count with much certainty on yields of from 250 to 300 bushels per acre, while exceptional yields of from 500 to 1,000 bushels per acre are obtained. The average yield in Great Britain and also in Germany is practically double the average in the United States. The fact that the average results in this country are so low is sufficiently indicative of the fact that the crop is often very unskillfully managed.

(*a*) *Varieties and seed* — New varieties of the potato are being constantly produced and sent out by seedsmen. The number of named varieties is very large, several hundred being known. These new varieties are produced by planting the seed of the potato berry or *ball*, as it is more commonly called. Considerable improvement, chiefly in the direction of earliness, has been made within the past twenty-five or thirty years. It is impossible to say which are the best varieties, but among those known by the writer to have valuable qualities may be named : —

1st. Early varieties : Early Rose, Beauty of Hebron, Early Maine, Early Dawn, and New Queen.

2d. Later varieties : Carmen No. 3, Fillbasket, Uncle Sam, and Burr's No. 1.

Without doubt it is of greater importance to secure seed of good individual characteristics, and from a suitable locality, than it is to pay high prices for the newest, highly praised name. In experiments on the grounds of the Massachusetts Agricultural College, seed of the same variety from different localities showed an amount of variation in yield almost equal to the extreme variation found among one hundred different varieties. The best Early Rose and Beauty of Hebron produced nearly one and one-half times the crop produced by the poorest; and this, where all the seed appeared to be of excellent quality, the difference being simply in location where the seed was raised. In experiments by Bailey, northern grown seed gave a crop four times greater than seed of the same variety from Pennsylvania. In one experiment by the writer, a number of tubers, as nearly alike as possible in size, form, and all exterior characteristics, were selected; each tuber was halved, and the halves planted in soil known to be perfectly even in quality. The yield from the different individual tubers showed a variation amounting to 22 per cent. Between the two halves of the same tuber there was, in some instances, a difference of 37 per cent. A candid consideration of these facts must convince one that comparatively little weight should attach to reported comparative yields, in experiments continued for one or at most only a few years, and on a limited scale. The location where the seed was grown, and its individual peculiarities, are of vastly more importance than name. In experiments on the grounds of the Massachusetts Agricultural College in 1899, ninety-four varieties being grown, twenty-six gave a yield at the rate of 333 bushels and over to the acre, the highest yield for any variety being a little over 500 bushels. There is evidently then no lack of good varieties; but the writer regards it as exceedingly significant that, in all his variety tests of potatoes, the old standard Early Rose and Beauty of Hebron have always been found among the first eight or ten varieties in yield and quality. Potato seed, as is evident from the results of many careful experiments at our various stations, as well as from the experience of practical men, should generally come from localities somewhat north of that in which the crop is to be grown; for the latitude of central Massachusetts, seed from northern Maine may generally be

counted upon to give good results. The crop is earlier and the yield heavier than with seed of home production, even in the first generation of home production. The writer prefers tubers of moderate size, smooth, and in form true to the type.

(*b*) *Soil and manures* — The potato will give largest yields on the medium loams, but for an early crop a loam inclining to be light is preferable, though if exceptionally sandy the crop is likely to be small in dry years. The potato does exceptionally well upon clover or grass sod, though the crop is perhaps not quite as early as upon old land. The grubs of the May beetle are, however, sometimes troublesome if the crop is put upon the freshly-turned, old sod The field should usually be plowed late in the fall. If sod, the fitting must be finished the following spring with the disc and other harrows. If old land is to be used for the crop, both fall and spring plowing may be desirable, for the potato delights in a well-mellowed soil. Fertilizers are in general preferred for this crop to manures. The crop is more certain to be healthy, more likely to be free from scab and rot, than when grown upon manures. This is especially true as regards the heavier soils ; on light soils manure is not objectionable.

On a medium loam in 1899 (which was a good year for potatoes), a remarkably good crop was grown on the grounds of the Massachusetts Agricultural College under the following treatment. The previous year the land had been in mixed grass and clover. Five cords per acre of farmyard manure from milch cows was spread on the soil early in the spring and plowed in. Fertilizers were used in the drill as follows, per acre : —

Nitrate of soda,	240 lbs.
Acid phosphate,	400 "
Sulfate of potash (high grade)	250 "
Tankage,	200 "
Dried blood,	100 "

These materials were mixed just before planting and broadly scattered the full length of the furrow before the seed was dropped. The crop was at the rate of over 275 bushels to the acre for almost all varieties grown.

In such experiments as have come under the writer's observation, the

application of fertilizers in the manner just indicated has invariably given larger yields in the case of the potato, than application broadcast. The potato does not have an extensive root system. It is most emphatically not a good "rustler." It thrives best with abundance of highly available plant food, placed in its immediate vicinity. Where the quantity of fertilizer used is large, it may be expedient to apply some of the slower acting materials broadcast, but where fertilizers are only moderately used it is believed that all should be put in the drill. It does not answer, however, to apply them in a narrow line. The materials should be spread over a strip 6 or 7 inches to a foot in width at least. It will be noticed that high-grade sulfate of potash is included in the above list of materials. It is believed that this potash salt should be selected rather than the muriate or kainite, on all medium to heavy loams. Not only is the yield greater but the quality is superior.

Muriate of Potash. Sulfate of Potash.

FIG. 161. POTATOES. Yield of one square rod each on muriate of potash and on high-grade sulfate of potash.

The Hatch Experiment Station of Massachusetts reports, as the result of fourteen experiments comparing high-grade sulfate with muriate of potash for potatoes, that the former has almost invariably given larger yields. As the average of all the experiments, if the yield of the sulfate of potash be represented by 100, that of the muriate is represented by 94. The sulfate, therefore, has given yields averaging 6⅓ per cent. greater than those produced by the muriate. On the basis of 200 bushels (which is about the average crop in Amherst), this means that the sulfate of potash will give 13 bushels more of merchantable potatoes per acre than the muriate. The value of that quantity of potatoes would range in different years from about $6 to $9. The sulfate of potash used per acre would cost about 75 cents more than the muriate. Here then we have a gain, very many times ex-

ceeding the increased cost, resulting from the use of the sulfate. Experiments in other localities, upon very light soils, have sometimes given results favorable to the muriate, but on the whole the sulfate must be regarded as a safer potash salt for general use for the potato crop. Where fertilizers are to be used alone for potatoes, it is recommended that from 1,200 to 1,600 pounds of mixture *H** be employed. All these materials may, without serious disadvantage, be mixed together and applied, about one-half broadcast, the balance in the drill; but it is preferable to reserve all the nitrate of soda, and one-half each of the blood, acid phosphate, and sulfate of potash for use in the drill, and to mix the balance of the materials when fitting the land, spread broadcast, and harrow in. The materials reserved for the drill should be put in at the time of planting.

(*c*) *Time and manner of planting* — The soil, in which a potato crop is to be grown, should as a rule be deeply pulverized. The crop is peculiarly susceptible to injury from drouth, and if the soil is shallow this injury is likely to prove serious. Potatoes should be planted rather deep, and when so planted there is less necessity for ridging to prevent exposure of the tubers to light and air. If planted by hand, it is a very good plan to open the furrow to a good depth, drop the seed in the bottom of the furrow, and fill the latter only partially; then, as weeds start and the crop grows, earth is gradually drawn into the furrow by the use of weeders and harrows. This is not only an advantage, on account of the decreased probability that the tubers will push up into the air, it is also an excellent method of helping to keep down the weeds which start along the rows. If an early crop of potatoes is desired the seed tubers should be treated as follows: —

About five weeks before they are to be planted, they should be washed and treated for prevention of scab as described below; and then spread in shallow layers, preferably only one deep, at most not more than two deep, in a moderately lighted room, the temperature of which can be kept permanently above freezing, and which will average by day in the neighborhood of 70° F, and at night not lower than 45° to 50°. Treated in this manner the sprouts begin to grow. They do not increase much in length but are very broad at the base and thick; they are green in color, and tough in

* For all fertilizer mixtures designated by letters, see pp. 539-541.

texture. The whole tuber meanwhile becomes green or reddish green. The sprouts which grow under such conditions are sufficiently tough to allow ordinary handling without serious breakage. Two or three days before ready to plant, the tubers should be cut into pieces of suitable size and dusted with plaster. They should be kept after cutting in small bulk only, in shallow boxes or in a very shallow pile. There is danger that they will heat, and that the vitality will be injured if they are put in large bulk or into close barrels or bags. Cutting a few days before planting allows the cut surface to dry and harden somewhat, after which the tuber seems to be somewhat

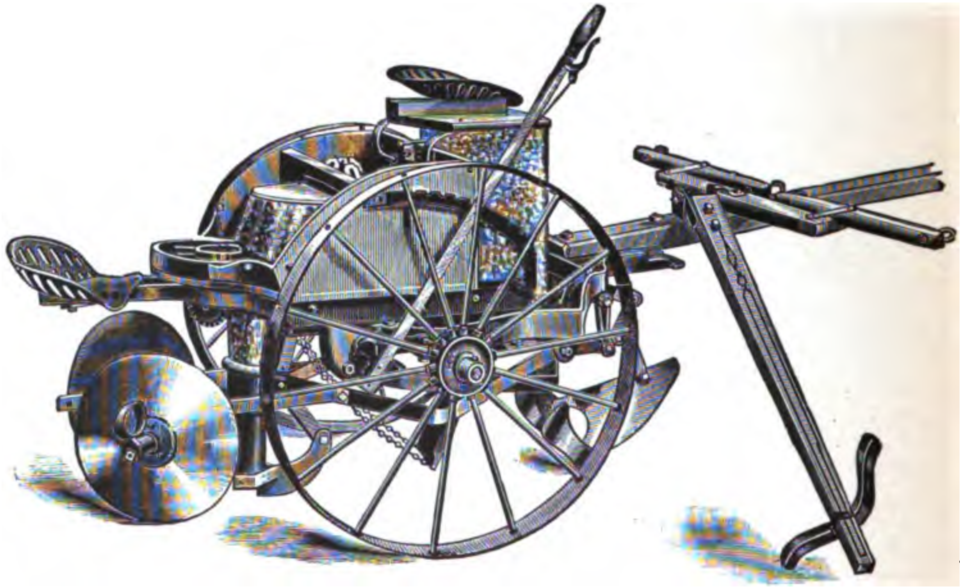


FIG. 162. THE ROBBINS POTATO PLANTER.

less likely to decay in the ground. Dusting with plaster seems also to lessen the probability of decay. As to the manner of cutting and the proper size of the seed pieces, there is considerable diversity in practice; but, if to be planted by hand, it will commonly be found best to cut the tubers lengthwise so far as possible into pieces of similar size and shape, containing from two to four eyes each. If the potatoes are to be planted by machine, it is necessary in order to insure even and certain planting that the pieces be somewhat blocky in shape and of rather uniform size. Special implements

for the rapid cutting of seed potatoes are made, but by the use of these, while pieces of even size and shape are produced, the number of eyes on the different pieces is likely to be very uneven, and results accordingly less satisfactory than those obtained where the seed is cut with a knife by an intelligent person. The potato can be quite rapidly and cheaply planted by hand. The covering can be done either with the tobacco ridger or with a plow. Potato planting machines of a number of different styles are made. The horse potato planter does its work in a most satisfactory manner. It requires for its operation two horses, a man, and a boy. It opens the furrows, drops seed and fertilizers, covers and rolls, at one operation. In large fields from 6 to 8 acres can be planted per day with rapid-walking horses.

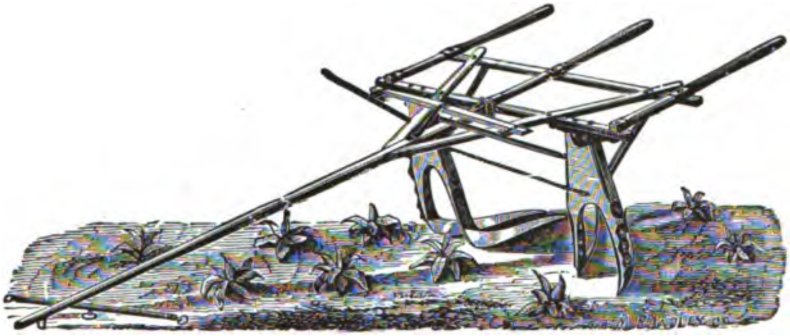


FIG. 163. PROUT'S HOE.

(*d*) *Cultivation of the crop*—The prime objects in the cultivation of the potato crop are to avoid the necessity of hand work, and at the same time to prevent the growth of weeds and maintain a surface mulch. Work should be very thorough up to about the time when the vines come into blossom, at which time the fields should be entirely free from weeds. The tops will then soon cover the ground, and cultivation at any later period is likely to decrease the yield. The weeder and harrow should be frequently used. The work should begin before the crop is up, and as often as weeds are seen to be breaking through the ground or the soil is found to be crusted the field should be gone over, first in one direction then in another. Select

for this work bright, clear days when the soil is not too adhesive. When the vines become too large for the use of these implements, ordinary cultivators which operate between the rows must be employed. The surface should be kept level up to the time of the last cultivation, and even then should not be ridged unless experience indicates that a considerable number of the tubers are likely to become exposed to the air. One of the best implements for ridging is Prout's horse hoe. This implement was invented primarily for the use of tobacco growers, being especially adapted to working close to the rows without injury to the leaves, its long blades running be-

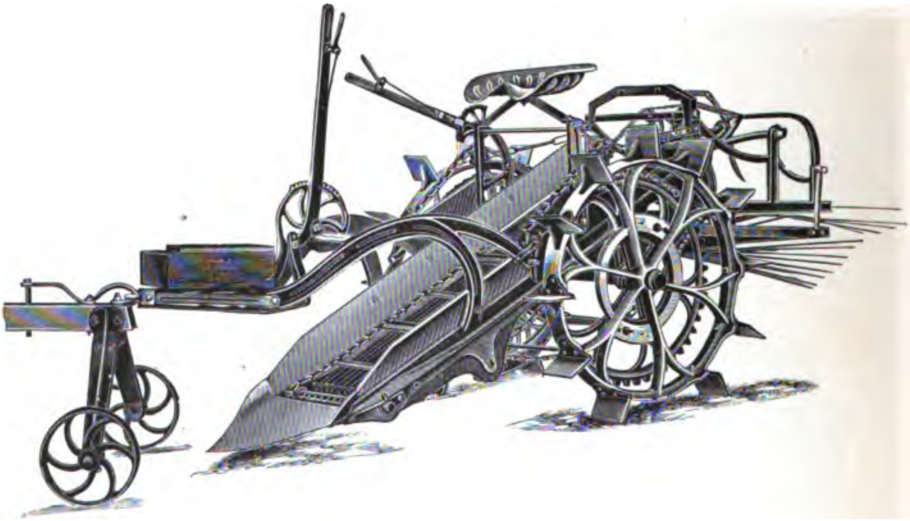


FIG. 164. HOOVER'S POTATO DIGGER.

neath them. These characteristics make this implement admirably adapted for use in the potato field, after the tops have become large. By its use a broad, low ridge can be made and this is far better than the narrow, high ridge so often seen in potato fields, because the roots of the crop are less injured, and injury from drouth less probable.

(*e*) *Harvesting* — Potatoes should be harvested if possible soon after the tops are dead. If left in the ground long, they are likely to be more or less injured by worms. In the majority of instances, in the New England

states, the crop is still dug by the use of the potato hook or fork ; but potato diggers are an assured success under the right conditions, and Hoover's potato digger is especially commended. By the employment of this machine, the crop may be much more cheaply harvested, where the fields are large, free from obstructions and weeds, than is possible by hand. For the operation of the machine, three or four horses are desirable, although two heavy draft horses can do the work in all soils except those which are exceptionally heavy, or where it is necessary to run deeply. One man with a suitable team will easily dig six acres a day. Fewer tubers will be injured than by ordinary hand digging. Most of the tubers will be left on the surface, so that they can be readily and rapidly picked up, the tops being

FIG. 165. POTATOES AS THEY WERE LEFT BY HOOVER'S DIGGER.

thrown to one side. In deciding upon the time of digging potatoes, the condition of the soil should be carefully considered. It should be moderately dry. If too wet, the quantity of earth adhering to the tubers is so great as to seriously injure their appearance. After digging, potatoes should lie upon the ground only so long as is necessary to dry off the surface. Protracted exposure to hot sun injures the quality.

(*f*) *Storing the crop* — Potatoes are best kept in cool, dry cellars in bins, which may be three or four feet in width and which should be so constructed as to allow some circulation of air.

(*g*) *Diseases of the potato* — The potato is subject to a number of diseases, which sometimes prove highly injurious. Among these, three will be spoken of.

Scab — Potato scab is caused by the growth in the surface tissues of the tubers of a parasitic fungus. The skin of potatoes is often roughened and rendered scabby by the attack of certain insects. For the prevention of injury due to this cause, the treatment to be described is useless. The fungus causing potato scab is a plant and grows from seed (spores). These spores may exist in the soil in which the crop is to be planted. This will be the case if a scabby crop has been grown in the field within a few years. Just how long the spores of the scab fungus retain their vitality in the soil is not known. When the soil contains spores of the scab fungus, there is no known treatment which will insure a healthy crop. Reports somewhat favorable to the use of sulfur, to the amount of about 200 pounds to the acre applied in the drill, have been made; but the favorable effects reported by some experimenters have not, as a rule, been obtained; and it

FIG. 166. FORMALIN TREATMENT FOR SCAB. 1 shows the condition of the tubers used for seed; 2, quality of the crop from untreated tubers; 3, quality of crop from tubers treated with formalin.
Courtesy of Indiana Experiment Station.

is now regarded by most as certain that it is unsafe to plant potatoes in infected soil, for the crop in such soil is sure to be diseased, in spite of any at present known treatment. If potatoes can be planted in clean soil, *i. e.*, soil free from spores of the scab fungus, scab can be practically entirely prevented — even although the seed used is scabby. There are several methods of treatment. The one now generally considered best is as follows: —

Take one-half pint formalin to 15 gallons of water. Formalin is a fluid which can be purchased in most drug stores. It is not poisonous and can be safely handled. Potatoes which have been treated should not, however, be used as food either by man or animals. In preparation for treatment it

is best to wash the potatoes, provided much earth adheres to them. They should then be soaked from 1½ to 2 hours in the mixture of formalin and water. The same solution may be repeatedly used. Just how many times is not known. A convenient method of treatment consists in putting the water and formalin in a barrel, the potatoes in an open woven basket or bran sack, and suspending them in the barrel so that they will be completely submerged. They should be shaken so as to insure that all will be reached by the solution. This treatment will not injure the vitality of potatoes which have not sprouted. If much sprouted, the tips of the sprouts are likely to be burned. Fresh sprouts will, however, start.

Early blight — This disease is due to the growth, in the tissues of the leaves, of a parasitic fungus, which soon causes the leaves to turn yellow and to dry up. This blight does not cause the tubers to decay. If it begins early, it however seriously decreases the yield, for the tubers cease growing when the leaves are killed. This blight can be prevented by spraying with Bordeaux mixture. The following directions for making Bordeaux mixture are quoted from Bulletin No. 60 of the Hatch Experiment Station : —

"Bordeaux Mixture Formula : 4 lbs. Copper Sulfate (Blue Vitriol).
4 lbs. Caustic Lime (Unslaked Lime).

"Dissolve the copper in hot water. If suspended in a basket or sack in a tub of cold water, it will however dissolve in from two to three hours.

"The lime is then slaked in another vessel, adding water slowly that it may be thoroughly slaked, then add enough water to make 5 to 10 gallons of the liquid. When both are cool, pour the lime into the copper solution, straining it through a fine meshed sieve or burlap strainer, and thoroughly mix. Before using, add water enough to make 50 gallons of the mixture, and strain again when poured into the pump. Many persons make the mistake, when preparing Bordeaux mixture, of straining the lime mixture while too thick, under which condition much of its value is lost. From five to ten gallons of water should be added to the lime wash before it is strained into the vessel containing the copper sulfate solution. The fine particles of

lime hold the copper and Paris green to the foliage and prevent injury, and, if properly strained, nearly all of this fine material will go through the nozzle without clogging.

"Stock solutions of both lime and copper, *i. e.*, 20, 36 or 48 pounds of each, may be prepared at one time and they will keep in good condition for a week or two, but they should *never* be put together until ready to be used. Before mixing, the lime solution should be thoroughly stirred and diluted.

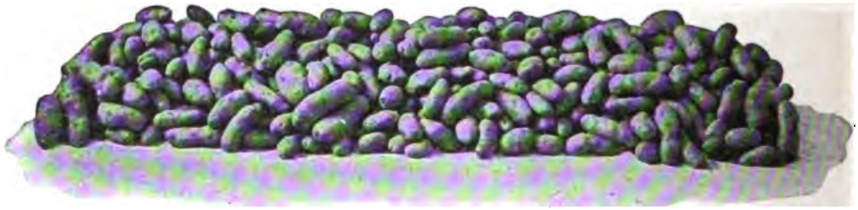


FIG. 167. TOTAL YIELD OF MARKETABLE POTATOES FROM TWO ROWS SPRAYED.

"The copper solution will retain its strength and value indefinitely, but the lime mixture is never as good as *within an hour or two* of the time it is made; and we would caution those purchasing the prepared Bordeaux mixture not to expect as satisfactory results as from the fresh, homemade mixture, which is also much cheaper.

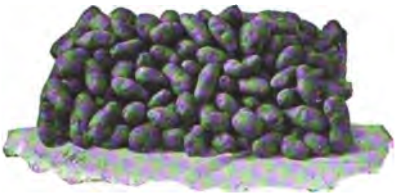


FIG. 167 *a*. TOTAL YIELD OF MARKETABLE POTATOES FROM TWO ROWS NOT SPRAYED.

"The active agent in this mixture is the copper, the lime being used simply to hold it in place upon the foliage and branches of the plants sprayed. Here it is given up with each rain, destroying the spores of the fungi as they are brought in contact with it by the surrounding atmosphere.

"Should the lime be air-slaked at all, more than four pounds may be needed, as it will have lost much of its strength.

"This fungicide is recommended as more satisfactory than any other, from the fact that it adheres a long time to the branches, buds, and leaves and seldom causes any injury to the foliage.

"It has been found more effective if made up fresh for each application."

Bordeaux mixture can be successfully applied only by the use of the modern spraying pumps and nozzles. There are many of these in the market. For use in the potato field where the crop is grown upon a large scale, a pump is needed of sufficient power to operate from three to five nozzles at a time, covering as many rows as rapidly as a team walks. A barrel pump of good capacity placed on any suitable truck, operated by a

Sprayed. Not Sprayed.

FIG. 167 *b*. From photograph of Experiment Station Potato Field, made September 10, 1892, showing results of three applications of Bordeaux Mixture. In connection see two preceding cuts, Figs. 167 and 167 *a*.

By courtesy of Vermont Experiment Station.

man who rides, will commonly be found the most satisfactory. A driver will be needed, for it is impossible for one man at the same time properly to drive and to pump, and a third man will be needed behind to control the distributing apparatus so that the nozzles may be kept directly over the rows. A length of gas pipe flexibly attached to the discharge, plugged at both ends, into which from three to four nozzles properly spaced have been

set, will be a satisfactory means of distributing the spray. There is no patent on this system of spraying and any ingenious farmer should be able to fit up a satisfactory machine for himself. The Vermorel nozzle seems to be the one which is most generally satisfactory. It will not prove economical in the end to employ a cheap pump. All parts of the pump should be well constructed and should consist of material such as brass or copper, not

FIG. 168. SPRAYING POTATOES WITH MODERN MACHINERY.

readily corroded. Whatever the kind of pump employed, it is important that it be used carefully, that the Bordeaux mixture be carefully strained before use, and that all parts of the pump be kept oiled, and that, after using, the pump be cleaned by pumping through it sufficient water to clear it of corroding materials. Much judgment and skill are required for successful spraying and only intelligent persons should be employed in this work. The quantity of Bordeaux mixture required

per acre to satisfactorily cover the vines varies with their size, the range being from about 50 gallons when they are small to 150 gallons when they are full grown. Thoroughness is essential. One thorough application is better than a number of careless sprayings. It should be remembered that prevention of blight is the end aimed at, not cure. If the disease has made much progress, it will be impossible to save the vines. Spraying must begin early; in the latitude of central Massachusetts, usually from the middle to the last of June. As the vines grow or the mixture is washed off by heavy rains, they will require re-spraying, and the number of applications may vary from three to six according to the season. The practical farmer without experience will say this is too much trouble and expense, it cannot pay. The experience of many practical men and the most careful investigators, however, has led to an opposite conclusion. The amount of trouble and cost are small, the possible saving very large. As yet the number of farmers who spray for prevention of blight is small. In years when blight is prevalent the potato crop is likely to be high. Spraying may secure an increased yield amounting to one hundred or more bushels per acre, and such an increase, even at very moderate prices, will pay the cost of spraying many times over.

Late blight, or potato rot — The late blight or potato rot is caused like the early blight by a parasitic fungus which, in its early stages at least, is confined to the leaves ; later it may penetrate the stems and reach the tubers, whose decay it causes. This disease does not as a rule strike the crop until it is nearly full grown, but if the climatic conditions are favorable to its rapid increase it does enormous damage. Sometimes within a few days leaves and tops are entirely killed and the potatoes entirely destroyed. It is unnecessary to go into particulars. Potato rot is too well known to need description. This like the early blight can be prevented, and the treatment for its prevention is the same as that which has just been described — in short, spraying for early blight will at the same time, if carefully done, entirely prevent injury from potato rot. This consideration renders it doubly evident that the wide-awake farmer of to-day will spray his potatoes.

Insect enemies — The potato crop has two insect enemies which almost

invariably attack it, the flea beetle and the well known Colorado potato bug. The flea beetle eats small holes in the leaves, chiefly while the plants are comparatively young, in many cases converting the leaves into veritable sieves. The injury from this insect is often overlooked. It will not destroy the crop but it seriously checks the growth of the plants. It may greatly enfeeble them ; and, in the opinion of men well qualified to judge, this very enfeeblement predisposes the potato to injury from early blight. Spraying with Bordeaux mixture, if begun early, will repel the flea beetle.

FIG. 169. LEGGETT'S PARIS GREEN GUN.

As is well known, the Colorado potato bug if unchecked will usually entirely destroy the crop. This insect must be poisoned and Paris green is almost universally considered the most satisfactory poison that can be used. This is applied in many ways : in mixture with plaster at the rate of about one pound of paris green to fifty of plaster ; in water at the rate of about one pound to one hundred gallons ; pure and in dry form ; and in connection with Bordeaux mixture. One of the two latter methods is recommended. Mixture of Paris green with plaster involves the handling of a very large amount of material, which of course increases cost. The same objection holds with even greater force as regards the use of Paris green and pure water. With one of the many forms of so-called insect powder or Paris green guns, the pure Paris green can be put on rapidly, easily, and in such a manner as not in the least to injure the vines. Leggett's gun is named as one which has been generally found very satisfactory. With this little implement Paris green can be put on at the rate of from about one-half to one pound per acre, which will be suitable quantities. This work should be done if possible while the vines are wet with dew. It can be done by a quick walking man at the rate of about an acre per hour. The use of Paris green in connection with Bordeaux mixture is, however, to be most highly

recommended, for as has been made clear the up to date potato grower will spray with Bordeaux mixture. He can, without increasing the expense in the least, save for the cost of the green, put this on at the same operation. One pound of Paris green to one hundred gallons of Bordeaux mixture is the right proportion.*

547. *Sweet potatoes* (*Ipomœa batatas*) — Though the sweet potato is classed with the Irish or common potato under tubers, it is, strictly speaking, only a very much thickened root — the portion of the root of the perennial plant in which a large store of nutriment has been packed away for the benefit of the new growth of the following year. The sweet potato is tropical or sub-tropical in its origin, and is especially adapted to localities having a long, hot season. The New England states are rather beyond the northern limit of its successful cultivation. It is largely grown in New Jersey; but, while it can be produced somewhat farther north, it is not of as good quality and is not likely to prove profitable. The sweet potato is suited to the lighter and warmer soils. It is propagated by planting the potatoes in beds in which they are placed closely together. In these beds the roots soon send up sprouts, and feeding roots develop on these sprouts. When the sprouts are a few inches above ground, they are separated with their attached roots from the potato and set in the field. The first set of sprouts having been broken off, a second set will be produced within a short time, and so from a limited number of potatoes placed under favorable conditions a large number of sets can be produced. In the northern portion of the belt in which sweet potato culture is profitable, the potatoes are placed in hot beds for sprouting. Farther south it is unnecessary to follow this course, as they can be started sufficiently early without bottom heat. If the soil in which the potatoes are to be planted inclines to be heavy and cold, it will be an advantage in the north to prepare ridges which should be about three and one-half feet apart, and to set the young plants on these ridges. Sweet potatoes should be manured about like the common potato.

548. *Jerusalem artichoke* (*Helianthus tuberosus*) — The Jerusalem artichoke is a perennial plant, belonging to the sunflower family. It pro-

* Arsenate of lead, one pound to fifty gallons of water, is regarded as superior to Paris green by some. It does not act as quickly, but will not burn the foliage, and can be kept suspended in water better and sticks to the leaves longer.

duces tubers of considerable size in very large quantities, under favorable circumstances. These tubers are used in some countries as a table vegetable, but are not in favor in the United States. This crop is seldom grown, but is considered by some well qualified to judge as a profitable crop to raise for the production of food for swine. It thrives on light, poor soils. It requires warmth both in soil and in climate. It is propagated by planting the smaller tubers or pieces of tubers. It will come up year after year in the same ground and is said to be a difficult crop to eradicate. It requires little manuring or attention. The customary method of harvesting is to plow the land and to pick up all the tubers that can be readily found. Under such circumstances, there will remain in the ground a sufficient number of tubers to restock the field. When it is desired to rid the field entirely of this plant, hogs may be turned in, and as they are very fond of the roots they will work over the ground until all are secured. The Jerusalem artichoke is not, however, a crop that the author is inclined to recommend.

LXXVII — BULBS.

549. *Onions* (*Allium cepa*) — The onion is almost universally used as a table vegetable, and in many parts of the Northeastern states it is extensively grown and is one of the most important among the money crops of the farm. The capacity of the onion for production is very great. Crops of 500 or 600 bushels to the acre are common, while from 800 to 1,000 bushels are not infrequently obtained. At prices which may usually be counted upon, such yields bring in a very large money return in proportion to the area occupied. There are many varieties, among which three very distinct colors are represented, viz.: the white, the yellow, and the red. In the markets of the New England states yellow skinned onions sell most readily. Among the best varieties having such a skin are the Early Round Yellow Danvers and the Southport Yellow Globe. The Early Red Globe and the Southport Red Globe are reliable varieties of that type. The White Portugal is a very early, mild-flavored onion, suitable for family use but not a good keeper. The Southport White Globe is a better white variety for general cultivation.

(*a*) *Soil and manures* — Onions do best upon the medium to moderately heavy loams and should always be put after crops which have had clean culture. If the field be weedy, the cost of production is enormously increased, since all culture and weeding must be done by hand labor. Chiefly because of this fact, onions are often grown for many successive years upon the same field; as, having once been brought into the desired condition, the preparation of the soil and culture are less costly in subsequent years. The onion thrives much better under continuous culture upon the same ground than most crops, as it is not especially subject to diseases which tend to increase rapidly under such a system of management. Unless great care is taken, however, the gradual increase in onion smut finally compels the farmer to change to a new field. Among crops which are likely to leave the soil in good condition for onions, the carrot is perhaps the very best, though the potato, if well cared for, is also a fairly good crop for the onion to follow. The onion is a crop the cultivation of which is so costly and the possibility of production so great under good management and liberal treatment that very heavy manuring is wise. It is the height of folly to allow an onion crop to be pinched because of deficient fertility. Since farm and stable manures are often coarse and usually carry weed seeds whose presence increases the cost of production, many prefer to depend exclusively upon fertilizers for the onion crop. Manures if used must be fine if they are to be put on in the spring. Coarse manures should be plowed in in the autumn. An abundance of lime in the soil is highly essential to

Nitrate of soda, 320 pounds; dissolved boneblack, 640 pounds; muriate of potash, 320 pounds per acre; yield, about 500 bushels per acre.

Muriate of potash, 320 pounds per acre; yield, 389 bushels per acre.

FIG. 170. ONIONS, in the eleventh year of continuous manuring as indicated; second year after liming at rate of one ton per acre of quicklime. Each cut shows total product of 1-40th acre.

success in onion growing and in all soils, except those naturally very rich in this constituent, onion land should receive an application of lime at the rate of at least one ton to the acre, once in six or seven years (390). The onion crop appears to be largely dependent also upon a liberal supply of potash, and this should usually be the most prominent ingredient in fertilizers for this crop, and the sulfate of potash has been shown by experiment to be considerably superior to the muriate. A liberal use of acid phosphate or dissolved boneblack favors perfect ripening of the onion crop ; and in any locality where there is difficulty in growing a well ripened crop, where the proportion of thick-necked onions or scallions is large, acid phosphate should be very liberally used. The proportions of the different fertilizer elements for onions should be about the same as for potatoes, and, if fertilizers only are to be used, it is recommended that from 2,000 to 2,500 pounds per acre of mixture *H* * be employed. The material should be put on after plowing and well worked in by harrowing.

(*b*) *Time and manner of planting* — Onions should be planted as early in the spring as the ground can be brought into suitable condition. It is best that the field should be fall-plowed if the soil is at all inclined to be heavy, and it must be again plowed in the spring and worked repeatedly with the clod crusher and harrows of different types until it is brought into the finest possible tilth. Unless perfect tilth is secured the germination of the seed is apt to be uncertain, and the growth of the crop unsatisfactory. In all except soils of a very refractory character a sufficiently good finish can be given by the use of the Meeker harrow. Where the soil is heavy and inclined to be lumpy, those who cultivate the onion, even upon a very large scale, finish their preparation by hand raking. This of course is costly, and the necessity for it should be avoided if possible by selection of soils which will not need it. The onion is sown by means of special hand sowers, of which there are many patterns offered in our markets. A machine which sows at least two rows at one operation is in favor among all large producers. The proper distance between the drills is about 14 inches ; the quantity of seed required per acre, 4 pounds.

(*c*) *Cultivation* — As already indicated, the work in the onion field

* For all fertilizer mixtures designated by letters, see pp. 539-541.

must be wholly performed by means of human labor, and the various forms of shove and scuffle hoes or hand cultivators must be frequently run between the rows to keep down the weeds and so far as possible to maintain a surface mulch, while the crop must be weeded by hand two or more times. Onion weeders should get down on their hands and knees astride the rows and work with both hands.

(*d*) *Harvesting and storing*—The maturity of the onion crop is indicated by the falling down and gradual dying of the tops; and when most of the tops have gone down and a large proportion of them are nearly dead the crop should be pulled and thrown into broad, shallow windrows or, if heavy, left to cover the entire field. Here they must lie until the tops are entirely dead. If the weather is continuously good, they may need no attention; but if heavy and long-continued rains come they may require stirring, and a short-tooth wooden rake is the best implement that can be used for turning them. When the tops are fully dry, a good day must be selected for taking the crop to the storehouse. It is highly important that it be well dried as otherwise it will not keep. Opinions differ as to whether it is best to cut the tops at the time the onions are stored or to leave them. Many large growers, having a perfectly ripened crop, prefer to leave the tops, storing in bins of moderate capacity or in barrels in which openings have been cut in three or more of the staves to allow some circulation of air. A dry, cool cellar is well adapted for the preservation of the crop. It should be so arranged that the windows can be opened during the cool nights of the autumn, in order to maintain a uniformly low temperature. If this matter is not attended to, many of the bulbs may begin to grow, after which decay is likely to set in. In localities where onions are largely grown, special storehouses are constructed for keeping the crop. Such storehouses are sometimes put up by individuals who undertake the storage of the crop for a small charge per bushel; sometimes by a co-operative association among the farmers themselves. Either system has much to recommend it. The crop cannot be successfully kept without considerable attention. This the individual farmer is not always prepared to give; but, when large quantities are stored in specially constructed houses and put into the charge

of an experienced man, the cost of the necessary attention per bushel is very low, and the crop is better cared for than it is likely to be if the work is left to the busy farmer.

(*e*) *The new onion culture* — Within recent years, an entirely new method of cultivating onions has been urged upon the attention of farmers and gardeners. This consists in sowing the seeds in beds and setting the young plants in the field. This system is better adapted to conditions existing in market gardens than to farm conditions. The advantages claimed for it are that the crop is earlier; that it is possible to cultivate some of the more delicate foreign sorts, which bring high prices in our markets, and which cannot be cultivated where the seed is sown in the field; that this plan saves one or more weedings; and that very large yields are secured. The labor of setting is of course considerable, and it seems to the author doubtful whether under farm conditions the advantages will offset the increased cost of handling the crop in this way. If this plan is adopted, the seed is commonly thickly sown in hot beds or sometimes under glass, and the plants set in the field when three or four inches high. Where onions are grown for an early market, or a special trade, this system may prove profitable; but, for the main crop and the general trade, it is not likely to be adopted.

(*f*) *Diseases and insect enemies* — The chief diseases which affect the onion are smut, previously alluded to, and mildew. Both are caused by the growth in and on the plant of a parasitic fungus. Onion smut shows itself chiefly by the development of the characteristic black powder, produced by all the smut fungi. This is most abundant in the neck or bulb of the affected plants. An onion affected by smut is without value. No method of curing or certainly preventing is known. The disease does not, as a rule, increase rapidly. There will, at first, in any given field, be only a few plants attacked by smut. These should be carefully destroyed. The earlier this is done the more effective it will prove, because the spores will have scattered to a considerable extent before the onion crop is ripe. When a field, or a part of a field, is seen to be affected by smut, care should be taken not to carry the smut spores to portions of the field or to other

fields which are not affected. They are often carried by means of cultivators, hoes, etc., used first where the crop is affected and later in another locality.

Mildew can probably be controlled in a measure by spraying with Bordeaux mixture, in the same manner as potato blight is prevented; but the injury is not usually sufficiently serious to make spraying profitable.

Among insects the onion maggots and the onion thrips are the only ones ordinarily seriously injurious, although cut worms occasionally destroy many plants. The onion maggot is more injurious upon moderately light than heavy soils. No satisfactory method of repelling this insect or destroying it is known. The usual course is to give up onion culture on fields where this pest is serious.

Onion thrips in dry seasons frequently do much damage. The crop when attacked by this insect gradually turns white, the leaves become dry and frequently die. This injury to the leaves checks the growth of the bulb. Experiments carried out in a number of places in this country indicate that, if a few rows of set onions are planted on the margin of the field and these be sprayed every week or ten days with kerosene emulsion, the main crop is protected. The set onions, being earlier than the others, the thrips begin their work on them; and, being destroyed by the kerosene emulsion, the danger to the main crop is avoided. Kerosene emulsions are made in various ways. One of the most useful is made as follows:—

"*Kerosene Emulsion Formula: ½ lb. common bar soap.
2 gallons common kerosene.

"Cut the soap into small pieces or shavings and dissolve in about two gallons of hot water. While still hot, pour in the kerosene and with the hand pump or syringe pump it back and forth until a thick, cream like substance is formed. In this condition the kerosene is divided into very minute globules and will be readily diluted or suspended in water. Before using add water enough to make

(*A*) 10 gallons of emulsion.
(*B*) 20 " " "

*Bulletin No. 52, Hatch Experiment Station.

"Formula *A* to be used when the insects are in large numbers and the foliage is known not to be easily injured by it."

This emulsion must be applied by the use of a spray pump and special nozzle (546, *g*).

Protection from cut worms is secured by the use of poisoned bait scattered where these worms will feed upon it. Among the best of the different baits which have been used is a mixture of dry bran and middlings, equal parts of each, and Paris green at the rate of one part to fifty parts of the mixed bran and middlings. This mixture should be sown about the time the onion crop is coming up, on grass and weeds on the margin of the field, and, if the worms are abundant, may also be applied across the drills at intervals of a few feet. It can be put on successfully with an onion seed sower.

LXXVIII — MISCELLANEOUS CROPS.

550. *Cabbages* (*Brassica oleracea*) — The cabbage is a crop of almost universal use as a table vegetable and the aggregate demand for it is enormous. It is very extensively produced as a garden crop, but farmers in many localities will find it a profitable money crop. It is, moreover, of much value as a forage crop under some circumstances (529, *b*). The varieties which will be most profitably grown by the farmer are the later, large heading sorts. Such varieties as Jersey Wakefield, which has conical heads and is very early, and Henderson's Summer, which has larger, flat heads and is also quite early, may be grown with profit by farmers having unusually warm or early land; but their cultivation must be chiefly confined to market gardeners who start the plants in hotbeds or in hothouses. Among varieties more likely to prove generally profitable to the farmers who do not care to start the plants in hotbeds are Fottler's Early Brunswick, Henderson's Succession (both of which will mature if planted in the field in central Massachusetts as late as about June 20th), Stone Mason (a standard variety with remarkably hard heads of good size, requiring several weeks longer for growth than the two which have just been named), and Marblehead Mammoth (a very large, late variety, requiring a long season and very favorable conditions to produce a satisfactory crop). The

last named variety may be a profitable crop to raise for cattle food, but is hardly to be recommended for table use. Cabbages of the Savoy class, which have curled leaves and which are very tender and of delicate flavor, are not likely to prove profitable on the farm ; and the same may be said of the red cabbages, the demand for which is comparatively small, as these kinds are used solely for pickling.

(*a*) *Soils and manures* — The cabbage requires deep, rich soils, and medium to heavy loam which has good capacity to retain moisture will give the most certain crops and largest yields. Soils which contain a liberal amount of lime are especially suited to this crop and success with it is more certain in limestone regions than elsewhere, although by suitable manuring the crop succeeds in localities where lime is not naturally abundant in the soil. Reclaimed marshes will often give satisfactory crops ; but whatever the nature of the soil drainage must be perfect, otherwise the crop is almost sure to become diseased. Club root almost inevitably occurs where the drainage is imperfect. It is of the first importance that the cabbage be grown in rotation with other crops. Club root is almost sure to occur to such extent as to seriously diminish the yield, whenever the attempt is made to produce cabbages on a given field oftener than once in about four years. This disease is equally likely to occur when cabbages follow any other plant of the same family, such as English or Swedish turnips or cauliflowers, within less than about the number of years above named. The cabbage may follow almost any crop save one of its own family. It will do particularly well on clover sod.

(*b*) *Manures and fertilizers* — The cabbage is a very rank feeding crop. A heavy yield removes from the soil enormous amounts of all the elements of plant food. It seems to be dependent to unusual degree upon a very liberal supply of phosphoric acid in readily available form. Farmyard manures may be employed in large amounts for this crop with advantage ; but the manure from swine should be avoided, especially if refuse cabbages which are likely to carry with them the germs of club root have been thrown into the pens where the hogs are kept. The observation of practical farmers indicates that club root is likely to occur where hog manure is applied for the crop. Manures, if coarse, should be plowed in late in the fall or early

in the spring, at the rate of 10 to 15 cords per acre. In connection with a moderate dressing of manure, it is recommended that from 600 to 800 pounds per acre of fertilizer mixture *F** be used. This may be applied broadcast or very widely scattered in the hills in which the seed is planted. If fertilizers alone are to be employed, 1,500 to 2,000 pounds of mixture *F** per acre, spread after plowing and harrowed in, may usually be counted upon to give a good crop.

(*c*) *Time and manner of planting*—As already indicated, the farmer will not usually care to attempt competition with gardeners who start plants in hotbeds for the early market. He will grow cabbages as a late crop. When so grown it is best to plant the seeds in the field. The soil should be thoroughly worked a number of times before the seed is planted. The time to plant will vary with the variety. Such a variety as Fottler's Early Brunswick, if grown as a main crop for winter use, should be planted in the latitude of central Massachusetts from about June 15th to 25th. A variety like the Stone Mason should be planted about June 1st; the Marblehead Mammoth from about May 10th to 20th. The distance required between the plants varies widely with the variety—for Fottler's Drumhead, rows about 3 feet apart and plants in the row 2 feet; for Stone Mason, rows 3 feet apart and plants in the row 3 feet; for Marblehead Mammoth, rows 3½ feet apart and the plants in the row the same distance. The field, having been deeply plowed and thoroughly harrowed, should be marked both ways. The marker will make a very shallow furrow and 5 or 6 seeds should be dropped at each point where the lines made by the marker intersect. The seed should be covered lightly with a hoe. Care should be taken to spread the seed a little in dropping. If five or six seeds are scattered along a line about the same number of inches in length, the plants can stand for some time without injury, but if the seeds are dropped in a bunch they must be thinned very early lest they become spindling and crooked. It is a great advantage to plant in such a manner that a number of plants can be left in each hill for some time. Insects inevitably destroy a certain proportion, but if there are extra plants in the field they can be readily used to fill vacancies. If taken up with a trowel and immediately set, they will be but little checked.

---

* **For all fertilizer mixtures designated by letters, see pp. 539–541.**

(*d*) *The cabbage must be kept continuously and rapidly growing*—This is the best means of escaping serious damage from insects. The crop has very numerous insect enemies. If it is growing rapidly it escapes serious injury, but if growth is slow the plants are seriously weakened and the crop as a result is likely to be small. Frequent, shallow culture during the early stages of growth, maintaining surface mulch, and preventing the growth of weeds should be the rule. After the crop begins to head culture may sometimes with advantage be somewhat deeper, as a moderate amount of root-pruning, especially if the growth has been rank and the soil is retentive of moisture, seems to promote uniform heading. Our seasons vary so widely that it is sometimes difficult to so manage as to secure maturity at just the right time. Winter cabbages which head too early cannot easily be disposed of. They will not keep, and in seasons when the falls are unusually warm and frosts come late there is sometimes considerable loss due to the fact that the heads get overripe and split open. This can be in large measure prevented by going through the field and partially pulling such heads as seem to be full grown. If thus partially started from the ground the growth is checked, and the heads may perhaps be kept in good condition until the cool weather, when they will be salable or can be harvested and stored.

(*e*) *Harvesting and storing*—The harvesting of the cabbage crop should be deferred until the weather is cold. The crop is hardy and will not be injured by any temperature short of that which actually freezes the ground. The crop may be preserved fairly well by cutting the heads, stripping off the loose leaves, and putting on shelves in a cool, dry place. A cellar which can be well ventilated, and which is not too damp, will be best; although, where the crop can be watched and ventilation attended to and the temperature regulated, the heads may be kept in rooms above ground. If cabbages are to be kept until spring, it is usually best to store them in the open air. A strip about five or six feet wide in well drained soil may be deeply plowed, the earth loosened by the plow thrown out, then the cabbages (which have been pulled and the loose leaves removed) may be placed heads down in this shallow pit. They may then be lightly

covered with straw or seaweed and two or three inches of earth added. There is great danger of decay if the cover is made too heavy. As the season advances and the weather becomes colder, the covering of earth must be gradually increased. The final depth of cover required may be as great as a foot, though of course the amount needed will differ with the climate. No harm will be done if the heads are moderately frozen.

(*f*) *Diseases and insect enemies* — Almost the only disease from which the cabbage suffers to any considerable extent is club root. This is due to the growth of a plant of very low order in the cells of the roots. Affected roots develop club shaped swellings, often of very large size, and as a result are entirely unfit to discharge their proper functions. The plants whose roots become clubbed cease growing, and in extreme cases die. If the extent to which the roots are affected is slight, a head may be produced, but the proportion of good heads in a badly affected field will be very small. The practice of putting cabbages in suitable soils at rather infrequent intervals is likely always to be most satisfactory, but recent experiments indicate that the somewhat liberal use of lime may make it possible to produce a healthy crop upon the same field continuously. Lime should be applied very early in spring and deeply mixed with the soil. If the field is known to be infected, it should be put on the first year at the rate of 80 to 90 bushels per acre. If used continuously it is believed that the yearly application of from about 30 to 40 bushels of lime will suffice to keep the field free from club root, even though cabbages or other members of the cabbage family occupy the land every year.

Very recently cabbages in some localities have been seriously affected by black rot, which attacks first the outer leaves, which turn yellow and die in spots. These spots enlarge, following down the vein towards the stem and the base of the head, finally completely destroying the latter. Black rot is due to the presence of a parasitic fungus. The measures necessary to avoid it must be preventive, and consist in the practice of crop rotation and the avoidance of manures from any animals that have been fed cabbages showing this disease.

The chief insect enemy of the cabbage is the green cabbage worm. This

can be destroyed by the use of Paris green, which may be applied either in water in the proportion of one pound to one hundred gallons by the use of a spraying pump, or in dry form by the use of a Paris green gun (546, *g*). Care should be used not to apply Paris green after the crop begins to head, but if all the worms have been destroyed during the early part of the season this will not as a rule be necessary.

The cabbage louse, particularly in seasons when the weather is very hot and dry, or when the crop is growing slowly from any other cause, is occasionally highly injurious. This insect can be destroyed by the use of kerosene emulsion, which must be applied by the use of a spray pump and suitable nozzle (549, *f.*)

551. *Squashes (Cucurbita maxima) and pumpkins (Cucurbita pepo)* — Squashes and pumpkins are considerably cultivated by the farmers as field crops; the former may often prove a profitable money crop, even on farms some distance from market. Both the squash and the pumpkin may, under some conditions, be profitable crops for the production of food for cattle, by which they are highly relished. Among the most valuable varieties of squashes for table use are the Hubbard, Essex Hybrid, and Bay State. The Mammoth Yellow Chili is a variety which reaches enormous size. On warm soils it gives heavy yields. It is suited for cattle food. Pumpkins are now very much less used in cookery than formerly, the squash being generally preferred. The Sugar pumpkin is one of the best for this use, while the Large Field and the Michigan Mammoth are valuable sorts for stock food.

(*a*) *Soil and manures* — These crops require warm, light soils. They will do well on any land where corn succeeds. The soil should be rich in the mineral elements of plant food but not overrich in humus or in nitrogen. On soil containing too much organic matter or nitrogen, the vines make a very rank growth but the quantity of fruit produced is likely to be small. Farmyard manures may be wisely employed on the lighter soils which are not rich in humus. It will be best if the manure be coarse to put it on in the fall. If rotted it may be turned under in the spring. Fertilizers should as a rule be used in connection with

manures; 500 pounds per acre of mixture H*, applied in circles from 1½ to 2 feet in diameter where the hills are to be made, will be satisfactory. If fertilizers alone are to be used, from 1,200 to 1,600 pounds per acre of mixture H* are recommended. About two-thirds of this should be spread broadcast after plowing, and harrowed in; the balance put on as directed in case of fertilizers used in connection with manure.

(*b*) *Time and manner of planting* — These crops are warm weather plants. Nothing is gained by putting them in too early. It is best to wait until the soil is warm and the season well advanced. In central Massachusetts from about May 20th to June 10th is the usual season for putting in these crops. They should be planted in hills from 8 to 10 feet apart, the distance varying according to the habit of the variety. The seed should be used in somewhat liberal amounts because insects find the young plants exceedingly attractive, and under field conditions it is difficult to protect them. As soon as the plants are growing rapidly and insect ravages are believed to be nearly at an end, they should be thinned to two or three to a hill.

(*c*) *Cultivation* — Culture should be thorough in both directions up to the time when the plants begin to run, after which not much work can be done. In case the growth of vines appears to be exceptionally rank and it is feared that they will become too much crowded, fruitfulness is increased by pinching and pruning. This, however, should not as a rule be called for It is better, by suitable manuring and by leaving only a small number of plants in the hill, to avoid the necessity for pruning.

(*d*) *Harvesting and storing* — Both squashes and pumpkins are tender, and while the fruit so far as appearance indicates may not be very much injured by light frosts, experience has shown that the keeping quality is greatly injured by exposure to even quite moderate cold. These crops, therefore, should be harvested before even light frosts. In harvesting care should be taken not to break off the stems or bruise. Squashes or pumpkins which are bruised soon decay. These crops can be best kept in rooms above ground, the temperature of which must be carefully controlled. In specially constructed squash houses the walls are made double and shelves are arranged in tiers, one above the other, of such width that it is possible to

* For all fertilizer mixtures designated by letters, see pp. 539–541.

reach all parts of the shelf from passages which run through the building. The vertical distance between these shelves should be about three feet. They should be open so as to allow circulation of air, and the squashes should not be piled more than two or three deep. Windows and ventilators must be so arranged as to secure good circulation of air when needed. Artificial heat is necessary and the temperature must be steadily held in the neighborhood of from about 50° to 70° F. It requires much care and attention to keep squashes without serious loss from decay, and under the conditions prevailing on the ordinary farm it will seldom pay to attempt storing the crop over winter. Great care is essential, moreover, to exclude rats. which are very fond of the seed, and to remove decayed specimens frequently, since decay will rapidly spread from a rotted squash to sound specimens in contact with it.

(*e*) *Insect enemies* — The young squash vine is very attractive to numerous insects. The most serious pests are the striped bug and the stinking squash bug. Flea beetles also frequently do much harm while the plants are small. The most effective remedy for all these insects is Paris green, with which the vines should be kept dusted until they begin to run, after which time, if they have been previously kept free from bugs, they will not be seriously injured. Paris green may be applied in mixture with plaster (one part of the green to fifty of plaster) or by itself with a dry insect powder gun (546, *g*). Squash borers sometimes destroy many of the plants, working in the stem just below the surface of the ground. Injury from the borer can be prevented by thoroughly harrowing the ground where the crop has been grown in the fall with a disc harrow, and by careful plowing in the spring to the depth of from 6 to 8 inches. Particular care should be taken to completely invert the furrow, as the efficacy of the method depends upon burying the dormant insect to such a depth that it cannot emerge to lay its eggs.

552. *Tobacco* (*Nicotiana tabacum*) — Tobacco is a crop of much importance in some sections of the United States, but its culture is by no means general. It is a crop whose production requires the exercise of the highest skill and much experience. In the different sections where tobacco

is grown in the United States, a large number of varieties suited to quite different uses are produced, but in the Northeastern states tobacco is grown solely for the production of wrappers which are used in making cigars. The leading varieties are the Havana Seed-leaf and the Connecticut Seed-leaf. Very recently an effort is being made to produce Sumatra tobacco under cover. Whether this will prove a financial success cannot yet be regarded as settled. There are few crops offering larger returns to the successful grower than tobacco, but at the same time there are few so costly to raise and involving so many risks. To attain success experience is necessary, together with careful compliance with every requisite and prompt attention to every detail of the work.

(*a*) *Soil* — For the production of wrapper leaf, loams of medium to light character, of good depth, with perfect drainage, are best. The proportion of humus should not be large, for this would mean a leaf of dark color. The heavier soils, rich in vegetable matter, produce a dark, strong leaf which does not bring as high a price as the light colored leaf, which is the product of the light, sandy soils. The soils should be naturally rich in lime, or, failing this, lime must be applied in moderate quantities. It is the practice of good growers to put the crop for several successive years upon the same land. Land which has never been used for tobacco will not, as a rule, produce so good a leaf the first year as later. The crop is one making heavy demands upon the soil, which should be rich.

(*b*) *Manuring the crop* — Tobacco growers in the Connecticut valley, which is noted for producing good wrapper leaf, depend chiefly upon fertilizers. If manure is employed the quantity used is as a rule small. It may be greater in proportion as the soil is lighter and naturally poor in organic matter. Cottonseed meal is almost invariably used for tobacco, a ton to the acre being a common amount. Lime, at the rate of from 500 to 600 pounds per acre, is also generally applied. As a source of potash, of which tobacco requires an unusually large amount, cottonseed hull ashes are regarded as best, but the supply of these is not sufficient to meet the demand, and Canada wood ashes or high-grade sulfate of potash are largely used. If cottonseed hull ashes can be obtained, from 800 to 1,000 pounds

per acre are sufficient. Of Canada wood ashes, as much as one ton to the acre is often employed. If high-grade sulfate of potash is selected as the source of potash, from 250 to 350 pounds are employed. All the materials named should be spread after plowing, some few weeks before the plants are to be set, and well worked into the soil by the use of the disc harrow. In addition to all the above materials it is common to use in the ridges, upon which the plants are set, some 600 to 800 pounds of some special tobacco fertilizer. Sometimes a special tobacco fertilizer alone is used for the crop, one ton to the acre not being regarded as an excessive amount. Mixture *I* * has about the composition desirable in a tobacco fertilizer. Special attention is called to the fact that no materials containing chlorids should be used for tobacco. Muriate of potash and kainite are unfit for this crop (370, *b*, *c*). The high-grade sulfate of potash, though much better than potash salts containing chlorids, is not entirely satisfactory; and for this reason the German manufacturers are now offering both the carbonate and the silicate of potash. Experiments in Connecticut indicate that these salts will produce a leaf of better quality than that produced where the sulfate is used. The potash in the carbonate and silicate costs more than in the sulfate, but the better quality seems likely to much more than offset this difference.

In Dr. Goessmann's experiments with fertilizers for tobacco, very satisfactory results were obtained by the use of the following materials per acre: —

Nitrate of soda,	160	pounds
Cottonseed meal,	1,154	"
Cottonseed hull ashes,	1,142	"

(*c*) *Time and manner of planting* — Tobacco plants are always started in beds and transplanted to the field when they have made about three or four leaves. If the area under cultivation is moderate, the beds are commonly made in the open air, and they are sometimes left without cover. Where the area to be grown is large, it is necessary that the plants come into condition for setting at different times; accordingly a portion of the plants are started in hotbeds, others are started in glass or cloth covered

* For all fertilizer mixtures designated by letters, see pp. 539-541.

beds without bottom heat, while still others may be started in beds without cover of any kind. The plants may be set any time after all danger from frosts is over, and from that time in the latitude of central Massachusetts up to about June 25th. Nothing is gained by putting the plants out until soil and weather are warm. Cloudy or showery weather is, of course, desirable for the work. When such weather does not occur, the plants must be watered at the time of setting and perhaps later as well. The soil of the field must be very thoroughly prepared. It is commonly plowed in the fall, again in the spring, and repeatedly worked with harrow, clod crusher, etc. When the plants are ready to set, low ridges, which should be about 3 feet apart, are made, and on the ridges the plants are set about 20 inches apart. Much setting is still done by hand, but the tobacco-setting machine is an assured success. To operate the machine requires a pair of horses, a driver, and two men or reliable boys to feed the plants into the machine. The machine both sets the plants and waters them. The water is fed into the bottom of the furrow in which the plants are set, and is completely covered by the earth, which is pressed down about the roots of the plants. It is largely because of the application of water in this manner that machine setting is so superior to hand setting. In hand setting water is poured about the plants after they are set. A portion of this water evaporates, and it compacts the soil about the plant. Under these conditions a given amount of water is not nearly as efficient as when applied by the machine. However the plants are set, unless the weather conditions are very favorable, a portion will die. The field must be gone over one or more times to fill vacancies.

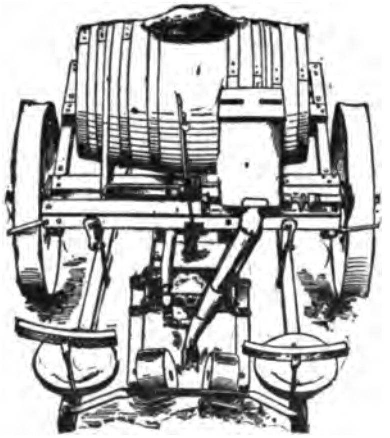


FIG. 171. TOBACCO TRANSPLANTER; may be used for cabbages, celery, etc.

(*d*) *Cultivation* — Tobacco must receive most careful cultivation. It

must be careful both as regards destruction of weeds and maintenance of a surface mulch, as well as avoiding injury to the leaf. A leaf which is broken or violently moved by careless cultivation is seriously injured. Soon after the plants blossom the tops must be broken off, the height of topping varying with the variety, the object being to produce leaves as even in size and quality and time of ripening as possible. Soon after topping, suckers start from the joints of the stem. These in turn must be pinched out.

(*e*) *Harvesting and curing* — To determine when the tobacco crop is ripe requires the exercise of a skilled and experienced eye and hand. To such it is indicated by a slight change in color and texture. The wrapper leaf of the Connecticut valley is harvested by cutting the plants close to the root. Most careful handling at this stage is essential in order to avoid injury. The plants after cutting may lie in the sun until moderately withered. They are then strung upon laths by use of special racks and a sharp point which fits thimble-like over the end of the lath. The plants thus strung are carried in long, low trucks with special frames on which the laths are placed, the plants hanging tops down. Wrapper leaf tobacco is cured as a rule in specially constructed sheds, in which the tobacco hangs in tiers, one above the other, and at such a distance apart as to allow circulation of air between. The crop requires careful attention throughout the period of curing, as, through carelessness at this stage, serious injury to quality is likely to occur. It is impossible to give directions which will enable a person without experience properly to attend to the curing of the crop. When cured, usually early in November, the crop is taken down from the poles, the leaves stripped from the stems, and made into bundles of uniform size and shape which are wrapped in paper. In this form the farmer usually sells his crop, the manufacturers as a rule preferring to assort and grade.

(*f*) *Diseases and insects* — The only disease which thus far has proved very serious in its effect upon tobacco is one which is known as the *Calico* disease. This name is given because of the peculiarly mottled appearance of the leaf due to the destruction of the green coloring matter and the formation of yellowish spots. This disease appears to be due to unfavor-

able conditions. It is believed to be due to physiological causes and not to the presence of parasitic fungi. No cure is known and probably none will ever be discovered. The remedy must be preventive and not curative. Great care must be exercised in the selection of soil and fertilizers and in securing for the crop all those conditions which are known to be most favorable for its continuous and healthy growth.

Among insects cutworms sometimes do great injury to the newly set plants. Whenever a plant is destroyed it is best to find the worm, which can usually be done by careful examination soon after the plant is cut off. Cutworms do their work at night and are in the habit of hiding in the loose earth in the immediate neighborhood of the plants they cut. They bury themselves but slightly.

The insect most feared is the large tobacco worm which feeds upon the leaves. The growth of the tobacco is so rapid that, if produced for any other purpose than a large and perfect leaf, the injury of the worm would not be serious ; but a leaf designed for use as a wrapper must be free from imperfections if it is to bring the best price. Tobacco growers therefore use great care to destroy these worms. The only method practicable is to search for them and to kill them when found. It will not answer to apply poison of any kind in the case of this crop.

553. *Broom corn* (*Sorghum vulgare*) — Broom corn is a more or less saccharine variety of sorghum, which is cultivated for its seed panicles, these being used for the manufacture of brooms and brushes. Broom corn does not differ materially in appearance from varieties of sorghum used for sugar, but the panicles are much larger and longer. During the early stages of its growth the plants strikingly resemble the ordinary corn. The culture of broom corn is by no means general. It was once very extensively carried on on the rich alluvial soils of the Connecticut valley. The competition of New York, and later that of states still farther west, many years ago rendered the cultivation of the crop in that section comparatively unprofitable, and it is not now of much importance in any of the Northeastern states, nearly nine-tenths of the total amount raised in the United States being produced in Illinois, Kansas, and Nebraska.

(*a*) *Soils and manures* — Broom corn can be profitably grown only on the better soils. The lighter soils, suited for Indian corn, will give good crops of broom corn. The manuring of the crop should be about the same as for Indian corn.

(*b*) Time and manner of planting are also the same as for Indian corn, save that the seed dropping attachment of the machine used must be slightly modified to suit the smaller size. Broom corn is best grown in drills, which should be about 3½ feet apart, and the plants should be thinned to about 6 or 9 inches. The culture is the same as for Indian corn, but will be more costly on account of the slow growth of the crop at first.

(*c*) *Harvesting* — For the best brush, broom corn must be harvested before the seed is mature. Should it be cut soon after the seed begins to form, brush of the very best quality is secured. It should never be harvested later than the period when the seed is in the milk. When ready to harvest it is customary to partially cut the stalks at the height of from about 2 to 2½ feet, bend the tops of two rows together, intertwining them in such a way as to make a table. At the same time the brush is cut with about 6 or 8 inches of stem below and laid on the table formed by bending down the stalks. The brush must not be laid upon the ground. It remains upon these tables but a very short time, as it must be cured under cover for the production of brush of good color. It should therefore be promptly carried to specially constructed drying sheds, where it is laid upon shelves. The sheds are so constructed as to permit the freest circulation of air in good weather. The seed is separated by drawing the brush through strippers. If a crop is not harvested until about the time the seed is in the milk, it will have considerable value for stock food, but if the brush is cut very early the seed will be of little value.

554. *The hop* (*Humulus lupulus*) — The culture of the hop in the United States, like that of tobacco, is highly localized. It is extensively grown in New York and farther west. The hop is a perennial plant and a hop yard, when once established, remains productive for many years. This species produces both male and female plants, and it is the latter only that produce the commercial hops for which the plant is cultivated. In

order that the female plants may produce hops of the best quality, it is however necessary that a certain proportion of male plants be set in the field with them. The usual proportion is about one male to one hundred female plants, the male plants being so placed as to be somewhat uniformly distributed over the area occupied by the crop.

(*a*) The soil for hops should be deep and rich and loams of medium character suit the crop best. A hop yard is started by means of root cuttings, of which about three or four are set in each hill. The distance between the hills varies from about 8 to 10 feet each way. Root cuttings produce plants of the same sex as the one from which they are taken. Hops are usually trained either upon poles alone, or, as is now generally preferred, upon a kind of trellis made by setting a pole — about six or seven feet above ground, and sufficiently deep to be firm — at each hill and connecting the tops of all the poles in the field by means of a network of stout cord. The plants, having climbed to the top of the poles, are then trained horizontally along the cords. In some cases much longer poles are set for the male plants, for, if these run up a considerable distance higher than the female plants, the pollen is more certainly and uniformly distributed by the currents of air by which it is transferred.

(*b*) A liberal use of potash salts is found favorable to the production of hops rich in *lupuline*, the bitter principle for which they are grown. If nitrogen and phosphoric acid, on the other hand, are supplied or naturally present in disproportionate amounts, the result is the production of hops of inferior quality, though very likely large in size. The soil intended for hops should be thoroughly and deeply cultivated and well enriched before the plants are set, and thereafter should receive yearly applications at the rate of from about 1,000 to 1,200 pounds per acre of fertilizer mixture *J* *.

(*c*) *Cultivation of the hop is not peculiar save in one respect* — Early each spring the hills must be opened down to the crown of the roots and all except three or four of the strongest buds removed. It is desirable that all the energy of the roots shall be devoted to the production of a few strong shoots, rather than that a large number of weak shoots should be produced.

* For all fertilizer mixtures designated by letters, see pp. 539–541.

(*d*) The crop is harvested, if trained upon high poles, by cutting the vines near the ground, taking down the poles, and laying them upon supports of convenient height for picking. If trained upon an overhead cord trellis, the clusters can be reached and cut from the ground, and taken in baskets to a convenient shed, where the hops must be picked by hand. When picked by either method hops must be rapidly kiln dried, after which they are baled and marketed as soon as may be. The chief use of the crop is in breweries. It is often exceeding profitable, but the yield is sometimes so abundant that the price is too low to afford a profit. It is not a crop which can be held long for higher prices as it deteriorates rapidly, however it may be kept.

555. *Fertilizer mixtures recommended*—In discussing the manurial requirements of the different crops which have been considered, definite advice has been given concerning the use of fertilizers. Different mixtures have been advised for different crops, and these mixtures have been designated by letters. These mixtures are given below. The number of pounds of each material which is to be used in 100 pounds of the mixture is stated. It will at once be seen that, in order to determine the amount of any material which must be purchased, the farmer has simply to multiply the number of pounds in 100 by the number of hundred pounds required for the total area in the crop to be manured. In most cases all the materials are to be put together and carefully mixed just before they are to be applied. Where this is not best this fact has been indicated in the discussion of the crop. The crops for which the several mixtures have been recommended are also here indicated, but, for advice as to the quantity which may wisely be used and the method of using, the reader must refer to the crop for which the mixture is to be used.

FERTILIZER MIXTURES.

		Pounds in 100 of the Mixture.	
A.	Fine-ground bone,	45	
	Acid phosphate,	10	
	South Carolina rock phosphate,	20	
	High-grade sulfate of potash,	25—	100

Wheat, spelts, rye, and peas and beans when the fertilizers are applied in the fall.

		Pounds in 100 of the Mixture.	
B.	Nitrate of soda,	20	
	Tankage or dry-ground fish,	15	
	Fine-ground bone,	20	
	Acid phosphate,	20	
	High-grade sulfate of potash,	25—	100

Oats and barley.

C.	Nitrate of soda,	20	
	Fine-ground bone,	30	
	Acid phosphate,	30	
	High-grade sulfate of potash,	20—	100

Corn, Kaffir corn, broom corn, and millet in connection with farmyard manures.

D.	Nitrate of soda,	10	
	Dried blood,	10	
	Tankage or dry-ground fish,	20	
	Acid phosphate,	30	
	High-grade sulfate of potash,	30—	100

Corn, Kaffir corn, broom corn, and millets on clover sod, peas and beans when fertilizers are applied in spring.

E.	Nitrate of soda,	10	
	Dried blood,	25	
	Tankage or dry-ground fish,	25	
	Acid phosphate,	20	
	High-grade sulfate of potash,	20—	100

Corn, Kaffir corn, broom corn, and millets on soils poor in humus.

F.	Nitrate of soda,	10	
	Dried blood,	10	
	Fine-ground bone,	30	
	Acid phosphate,	30	
	High-grade sulfate of potash,	20—	100

English turnips, Swedish turnips, and cabbages.

G.	Nitrate of soda,	15	
	Dried blood,	15	
	Tankage or dry-ground fish,	25	
	Acid phosphate,	20	
	Muriate of potash,	25—	100

Mangel-wurzels, sugar beets, carrots, and parsnips.

H.	Nitrate of soda,	10	
	Dried blood,	15	
	Tankage or dry-ground fish,	20	
	Acid phosphate,	40	
	High-grade sulfate of potash,	15—	100

Potatoes, sweet potatoes, onions, squashes, and pumpkins.

	Pounds in 100 of the Mixture.	
Nitrate of soda,	25	
Sulfate of ammonia,	10	
Dried blood,	10	
Dissolved boneblack,	35	
High-grade sulfate of potash,	20—	100

Tobacco.

Dried blood,	10	
Tankage or dry-ground fish,	20	
Fine-ground bone,	40	
High-grade sulfate of potash,	30—	100

Hops.

556. *General remarks on the fertilizer mixtures recommended*—While much care has been used in the selection of materials, as well as in deciding upon the proportions of the several constituents recommended in the above mixtures, attention is once more called to the fact that no farmer who follows empirical rules can hope for the highest success. Each should study his soil (413-421) as well as the markets (406) before deciding what to use. He who makes home mixtures, in accordance with the directions here given, will procure plant food at lower cost than he who purchases so-called "special fertilizers," but for the most economical results he must study the conditions of his own environment. In making up these mixtures it has been possible to take into account the peculiarities and the special needs of the different crops. It is clearly an impossibility to give directions which shall be universally applicable. The materials which have been recommended are such as are ordinarily obtainable at reasonable prices. The reader is not to understand that he must always have precisely the materials which have been indicated. By reference to what has been stated in connection with the different fertilizers (332-373), he will be able to learn what substitutions or changes may be made without detriment, in case the condition of the market is such that plant food in other forms can be procured at less cost. In case the farmer decides to use fertilizers in different amounts from those which have been recommended, it is advised that the decrease or increase shall affect each of the materials in the mixture, leaving them in the same proportion as advised, excepting of course in case the farmer, as the result of experience or direct experiment, finds that owing to the peculiarities of his soil or climatic conditions some change is called for.